

LMSC-F115808

Advanced Planar Array Development For Space Station

(NASA-CR-179372) ADVANCED PLANAR ARRAY
DEVELOPMENT FOR SPACE STATION Final Report
(Lockheed Missiles and Space Co.) 68 P

CSCI 10A

G3/44

Unclass
0094141

N89-10407

F I N A L R E V I E W

 Lockheed Missiles & Space Company

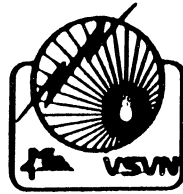
**ADVANCED PLANAR ARRAY DEVELOPMENT
FOR SPACE STATION
FINAL ORAL REPORT
MAY 19, 1987**

SUBMITTED TO

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER**

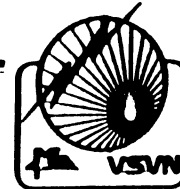
CONTRACT NO. NAS8-36419

AGENDA

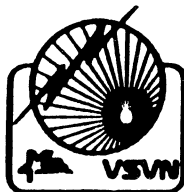


- OBJECTIVES
- APPROACH
- TASK DESCRIPTION
- PROJECT FLOW DIAGRAM
- SCHEDULE
- PROGRESS
 - SUPERSTRATE AND CONVENTIONAL MODULE DESIGN (TASK 1.0)
 - PROCESS DEVELOPMENT
 - FABRICATION AND TEST (TASK 2.0)
 - THERMAL CYCLE TESTING (TASK 2.1)
 - THERMAL BALANCE TESTING (TASK 2.2)
 - 15" X 50" PANEL SEGMENT (TASK 2.3)
- SUMMARY
- ADDITIONAL WORK

OBJECTIVES



- DEVELOP PROCESS FOR MANUFACTURING SUPERSTRATE ASSEMBLIES
- DEMONSTRATE SUPERSTRATE TECHNOLOGY THROUGH FABRICATION AND TEST
- DEVELOP AND ANALYZE A PRELIMINARY SOLAR ARRAY WING DESIGN
- FABRICATE A WING SEGMENT BASED ON THE WING DESIGN

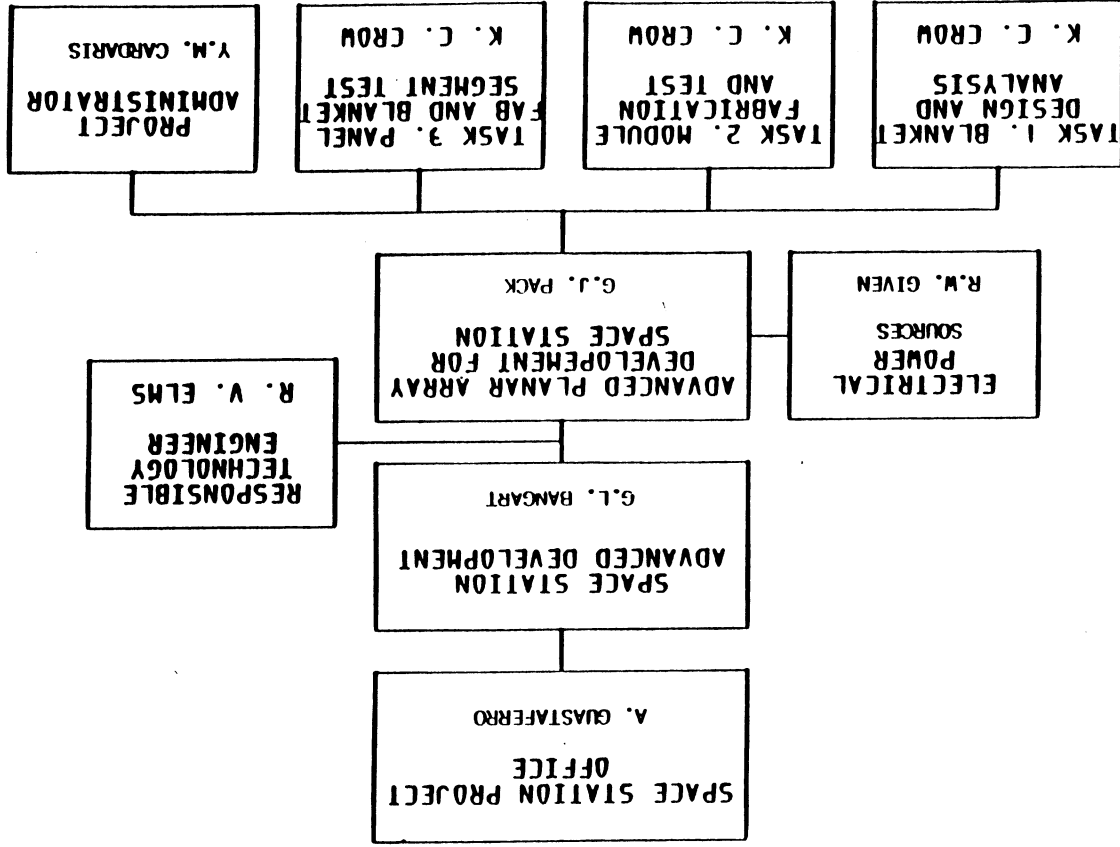
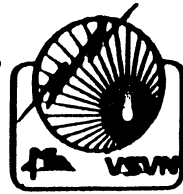


TASK DESCRIPTION

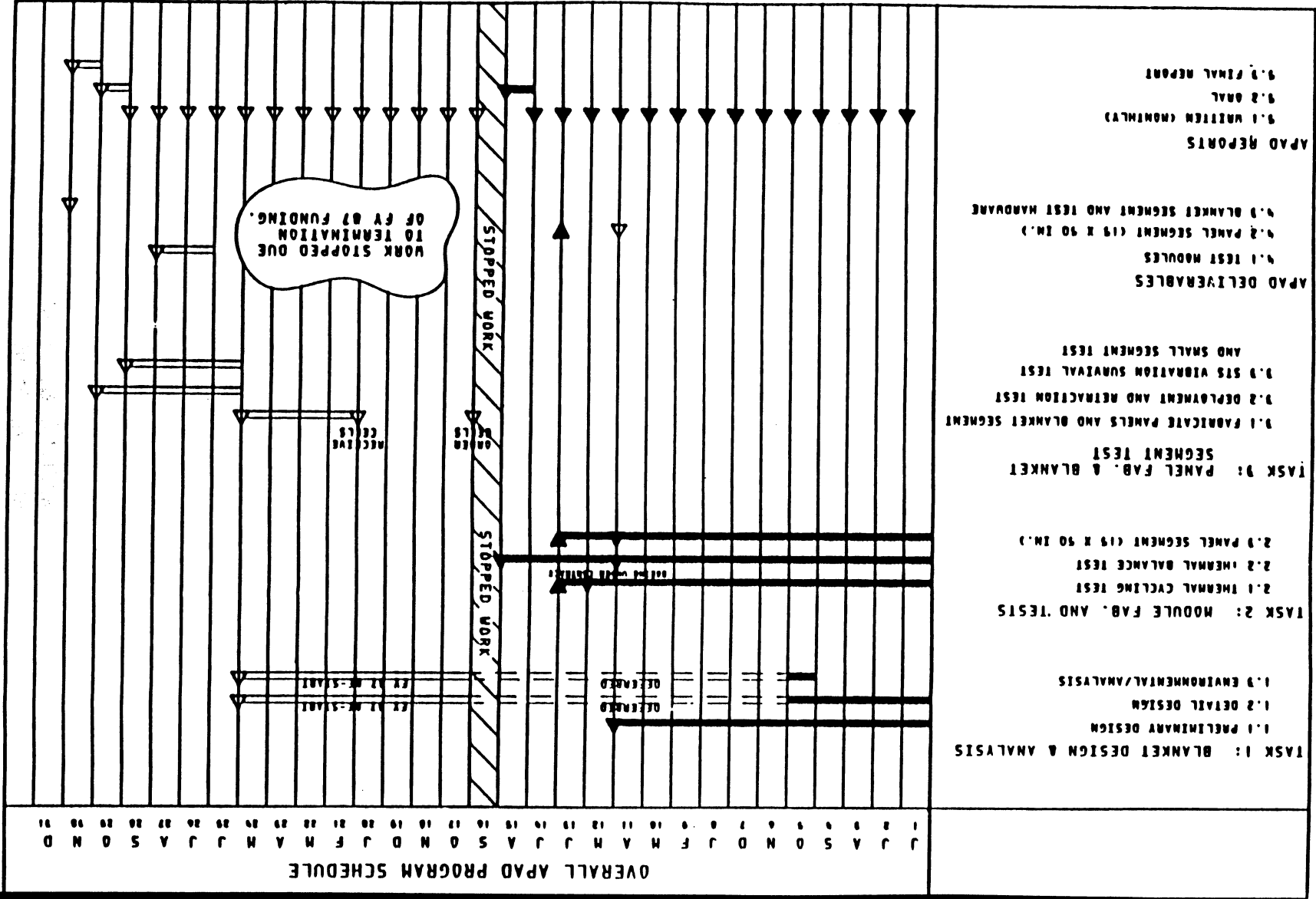
TASK 1.0 WING DESIGN AND ANALYSIS
* 1.1 DEVELOP PRELIMINARY DESIGN OF A SOLAR ARRAY WING
1.2 DETAIL DESIGN
1.3 ENVIRONMENT/ANALYSIS
1.3.1 GROUND HANDLING ENVIRONMENT
1.3.2 SHUTTLE ORBITER LAUNCH AND REENTRY ENVIRONMENTS
1.3.3 LOW EARTH ORBIT OPERATIONAL ENVIRONMENT
1.3.4 RESULTANT ELECTRICAL PERFORMANCE
TASK 2.0 MODULE FABRICATION AND TESTS
* 2.1 THERMAL CYCLE TESTING
* 2.2 THERMAL BALANCE TESTING
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TASK 3.0 PANEL FABRICATION AND TESTING
3.1 FABRICATE SOLAR ARRAY PANELS
3.2 DEVELOPMENT TESTING
3.3 STORAGE AND SMALL SEGMENT TESTING
TASK 4.0 DELIVERABLES
4.1 FINAL REPORT
4.2 ALL MODULES TESTED IN TASK 2.0
* 4.3 15" X 50" WSFC TEST MODULE
4.4 WING SEGMENT AND DEPLOYER
TASK 5.0 REPORTING
* 5.1 MONTHLY PROGRESS REPORTS AND MANAGEMENT (FINANCIAL) REPORTS
* 5.2 MID-TERM ORAL PRESENTATIONS
* 5.3 FINAL ORAL PRESENTATION
5.4 FINAL COMPREHENSIVE REPORT

* COMPLETED

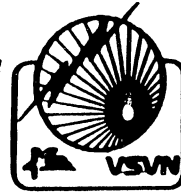
PROJECT ORGANIZATION



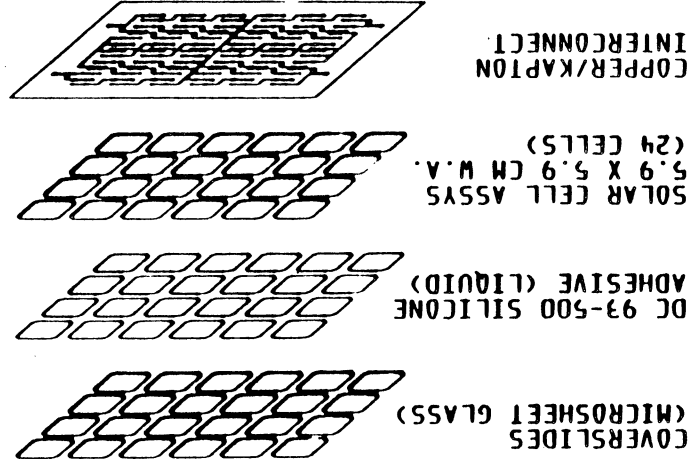
PROGRAM SCHEDULE



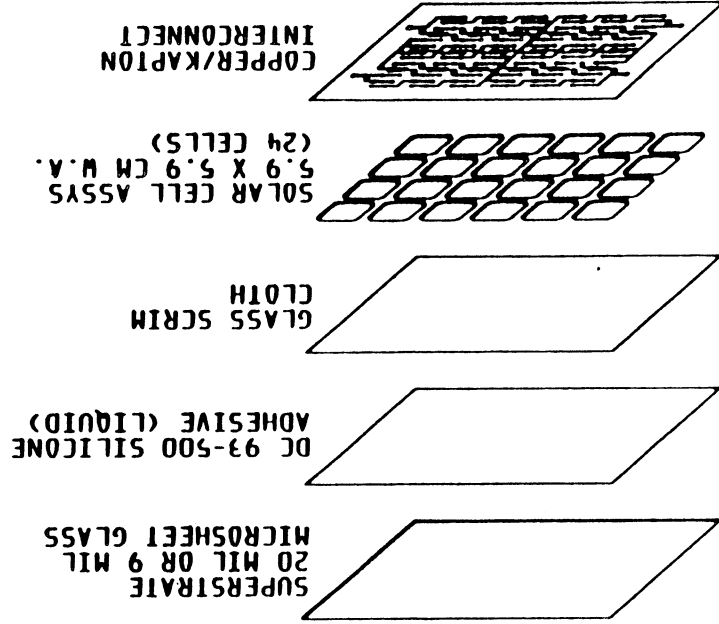
MODULE ASSEMBLY - SUPERSTRATE VS CONVENTIONAL



CONVENTIONAL MODULE



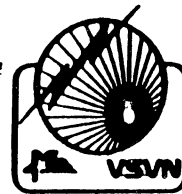
SUPERSTRATE MODULE



LARGE AREA SOLAR CELL DESCRIPTION

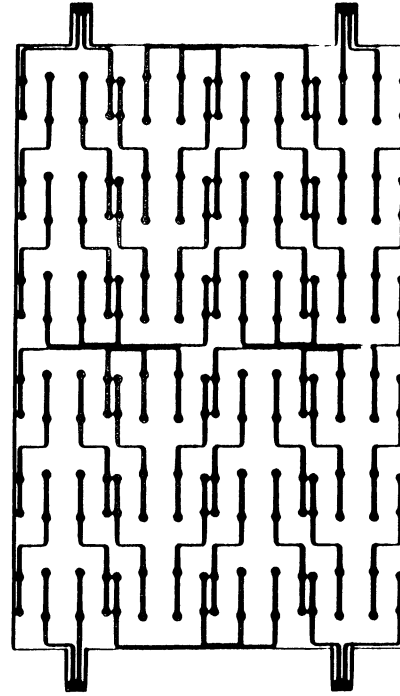


- 5.9 X 5.9 CM ROUNDED CORNERS (8 MILS THICK)
- WRAPAROUND "N" CONTACT
- GRIDDED "P" CONTACT
- 2 OHM-CM MATERIAL
- ELECTRICAL EFFICIENCY 13.2% AMO @ 25°C
- BACK SURFACE TREATMENT
 - OPTICAL COATING TO ENHANCE TRANSMISSION
 - ALUMINUM 2000-4000 ANGSTROM REFLECTOR



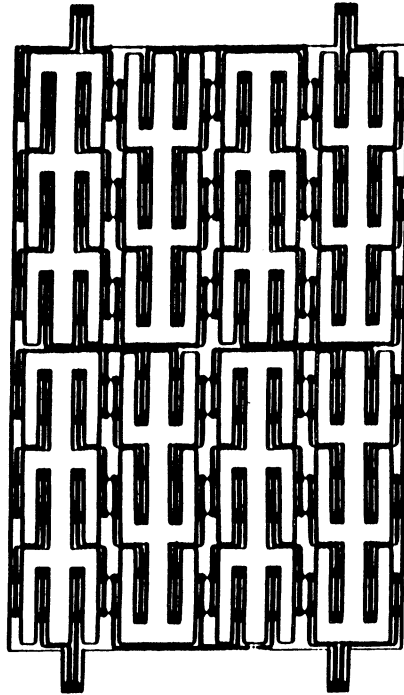
MODULE INTERCONNECTS

THERMAL CYCLE TEST



FULL KAPTON

THERMAL CYCLE TEST
PANEL SEGMENT

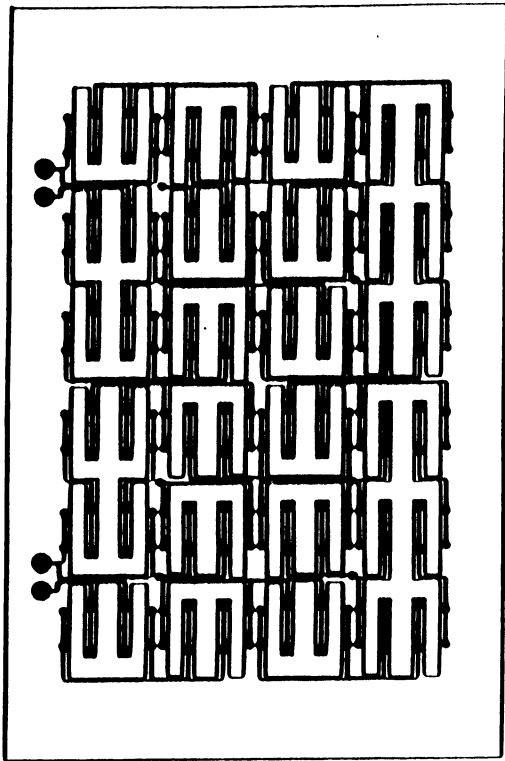


CUT-AWAY KAPTON

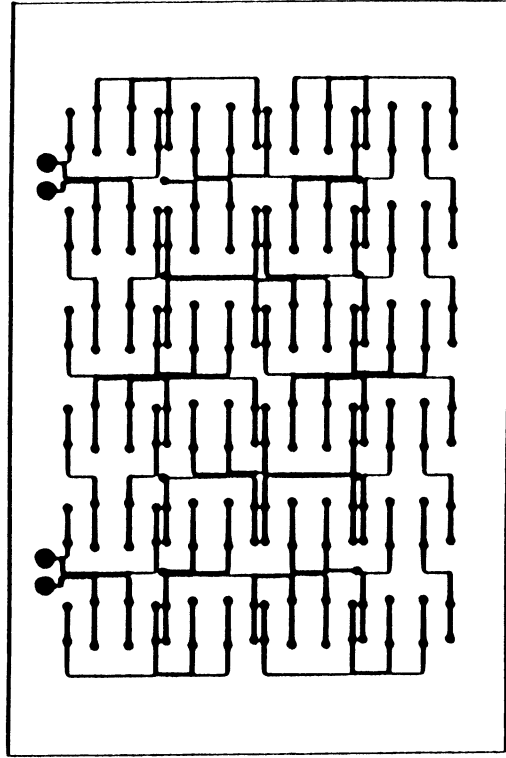
MODULE INTERCONNECTS



THERMAL BALANCE TEST MODULES

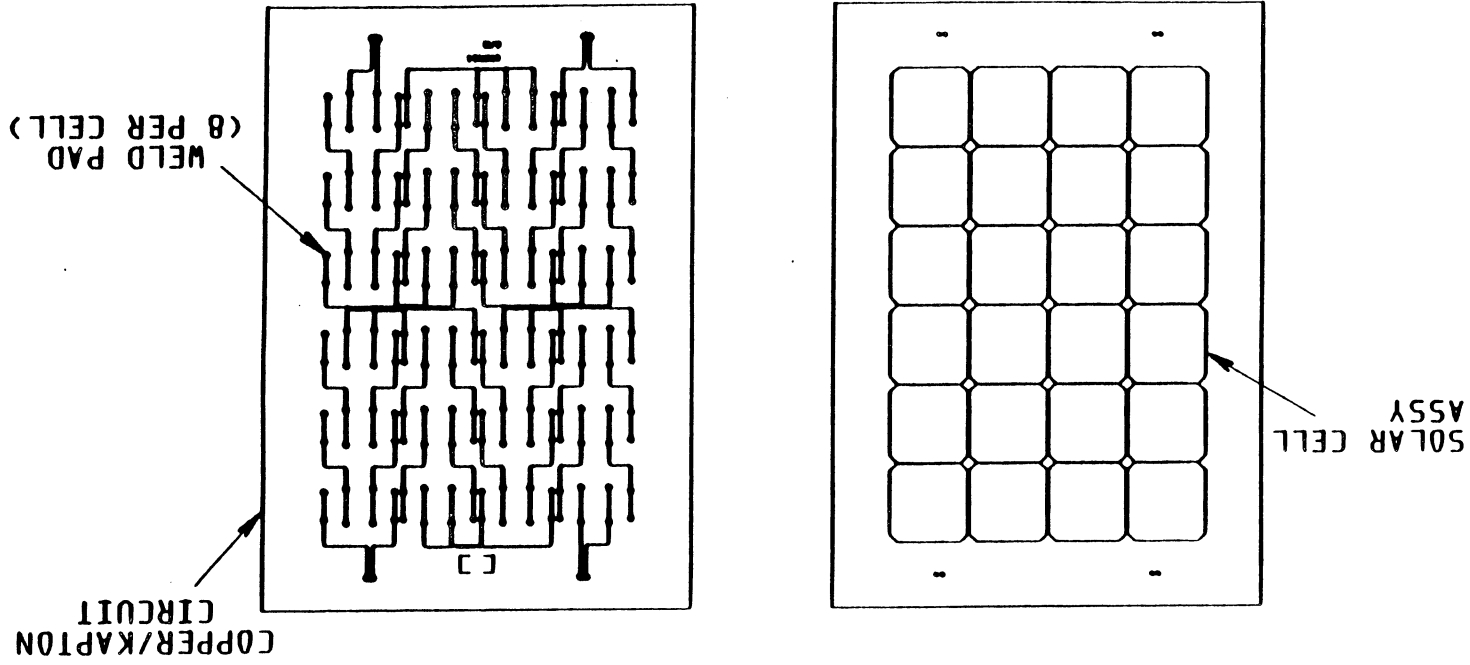
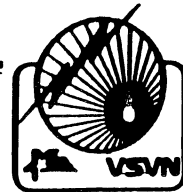


CUT-AWAY KAPTON

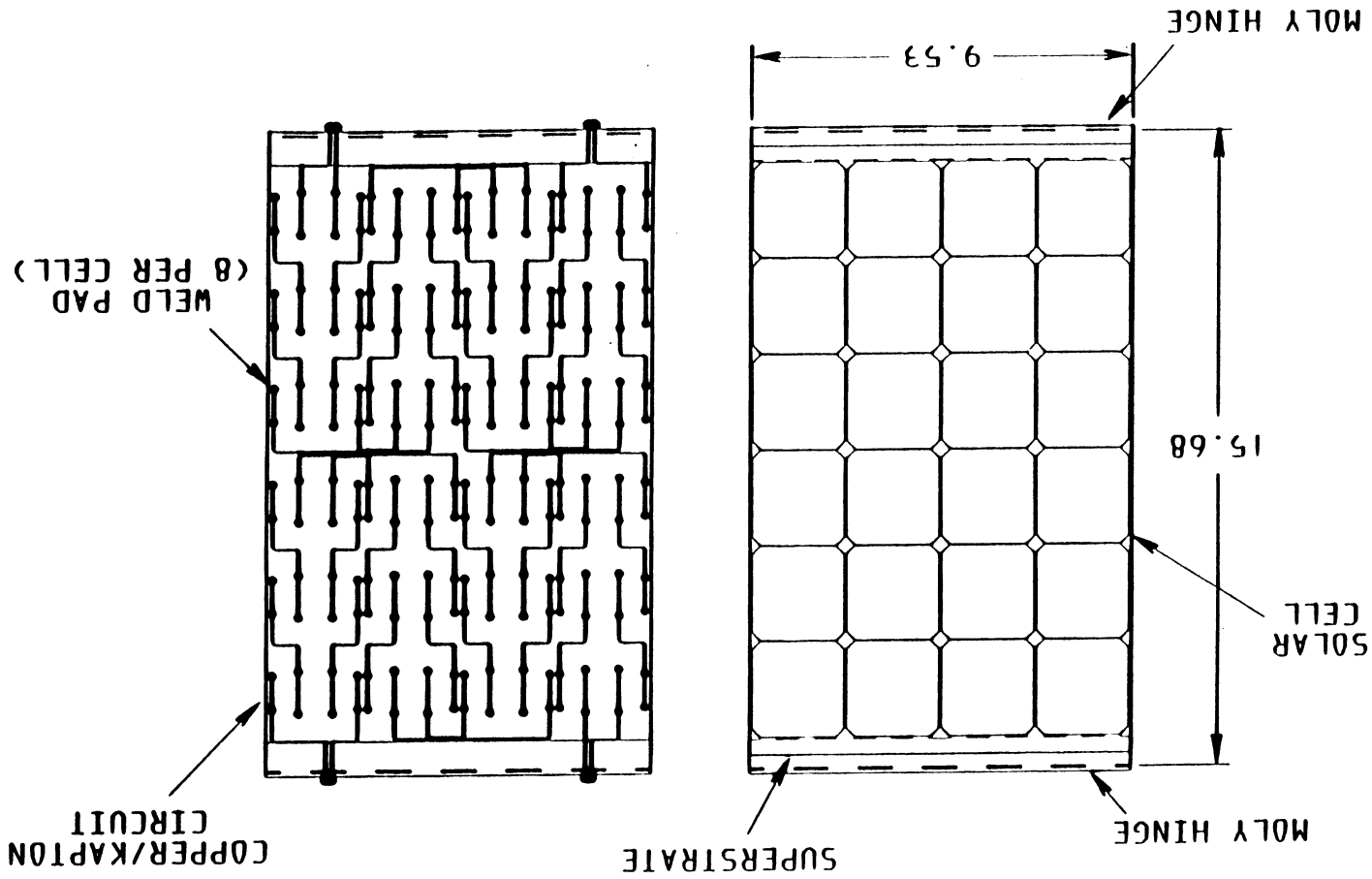


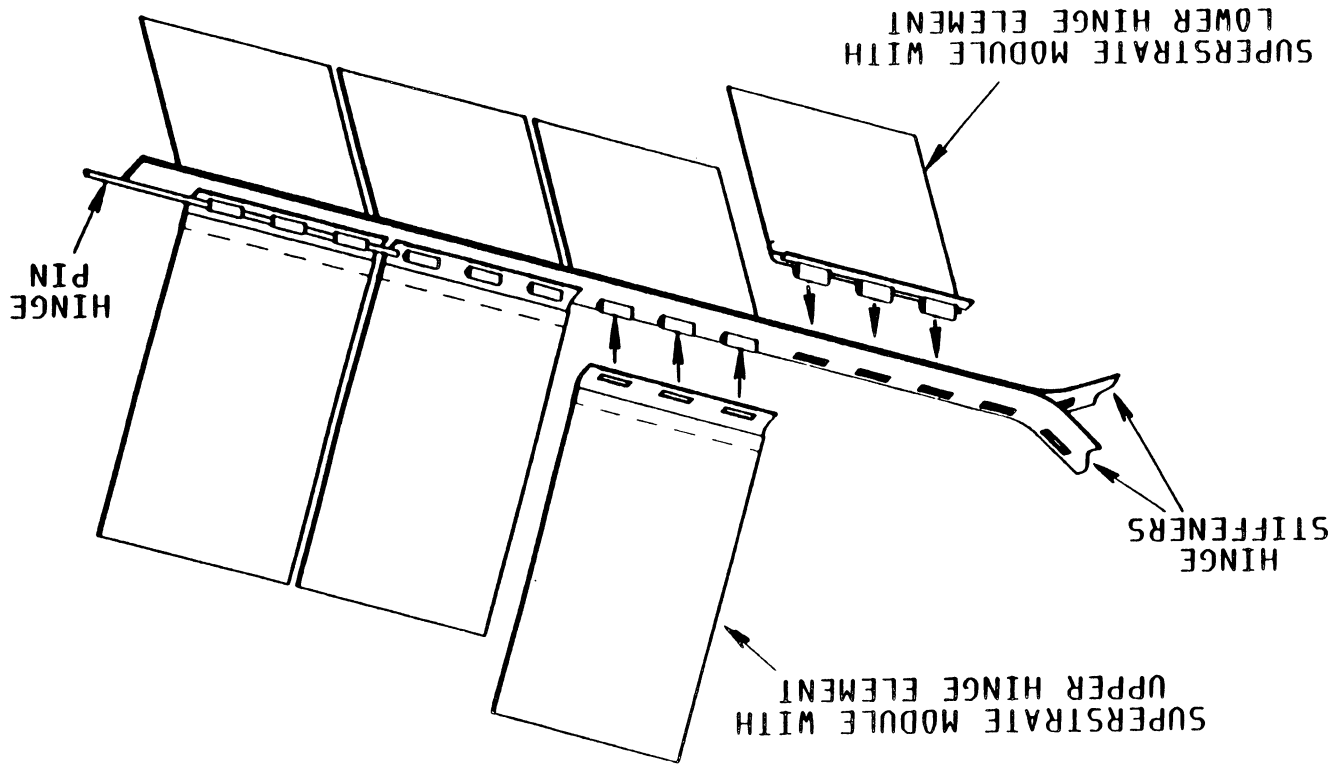
FULL KAPTON

CONVENTIONAL MODULE ASSEMBLY

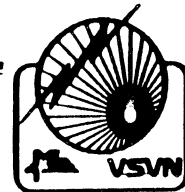


SUPERSTRATE MODULE ASSEMBLY

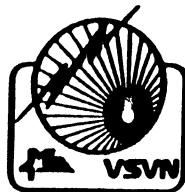




SUPERSTRATE HINGE



CONVENTIONAL LAYUP SEQUENCE



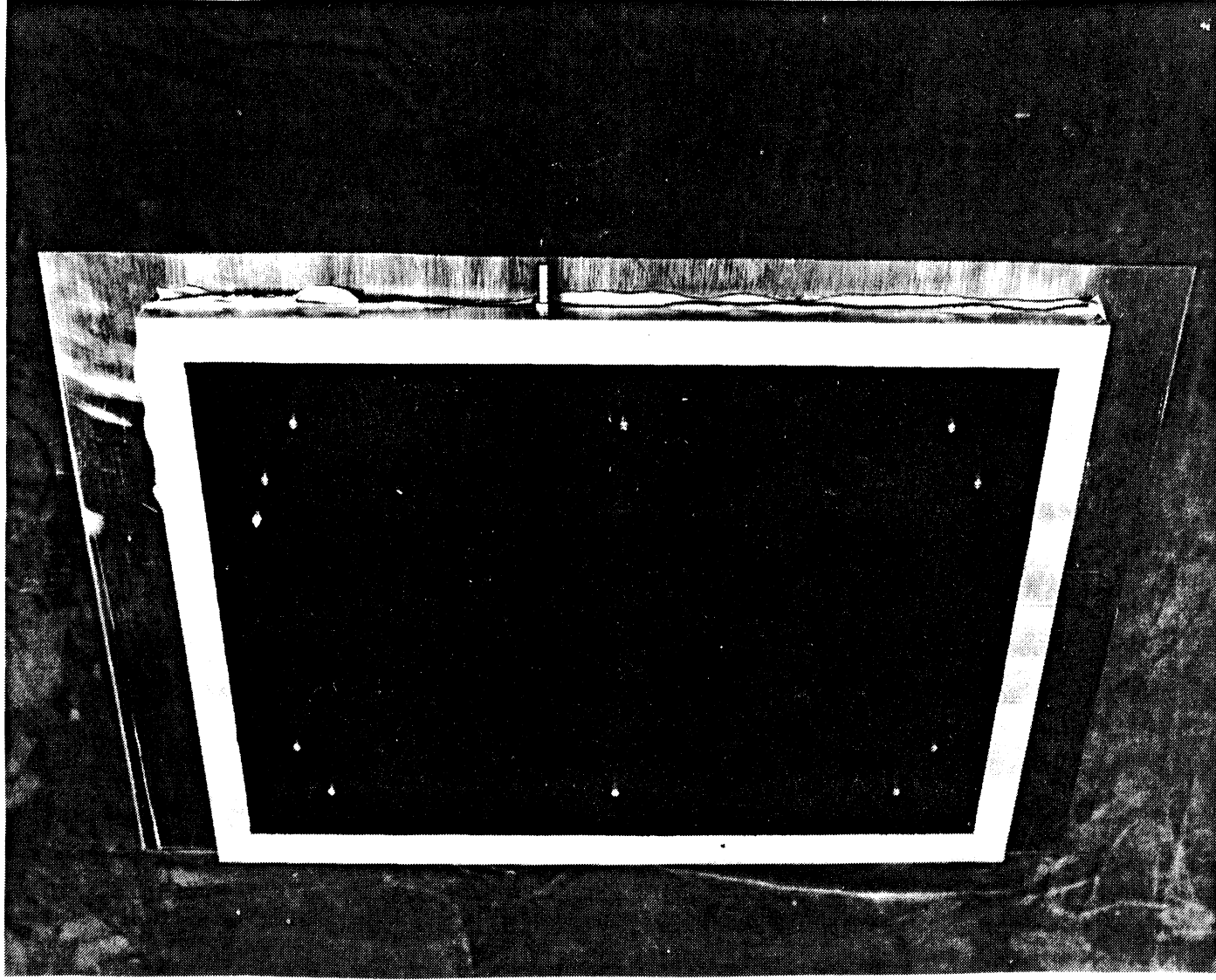
1. MANUFACTURE SOLAR CELL ASSEMBLIES.
2. PLACE SOLAR CELL ASSEMBLIES IN WELDING FIXTURE.
3. PLACE COPPER/KAPTON INTERCONNECT OVER SOLAR CELL ASSEMBLIES AND ALIGN WELD PADS TO ELECTRICAL CONTACTS.
4. TAPE COPPER/KAPTON INTERCONNECT TO SOLAR CELLS WITH LOW TACK TAPE.
5. WELD CIRCUIT TO SOLAR CELLS AND REMOVE TAPE.
6. ELECTRICAL TEST AND INSPECT.

SUBSTRATE LAYOUT SEQUENCE



1. 9.56" X 15.00" X .020" OR 9.56" X 15.00" X .009" MICRO SHEET
2. APPLY GLASS SCRIM CLOTH AND DC 93-500 ADHESIVE TO MICRO SHEET GLASS
3. PRE-CURE GLASS, SCRIM, AND ADHESIVE IN OVEN.
4. PLACE SOLAR CELLS IN SUBSTRATE BONDING TOOL (ELECTRICAL CONTACTS FACING UP).
5. MASK SOLAR CELLS WITH LOW TACK TAPE.
6. FLIP SOLAR CELLS OVER AND POSITION IN SUBSTRATE BONDING TOOL.
7. APPLY DC 93-500 ADHESIVE IN CENTER OF SOLAR CELLS.
8. PLACE PREPARED GLASS ON SOLAR CELLS AND SPREAD ADHESIVE WITH ROLLER.
9. CURE IN OVEN.
10. BOND HINGES TO SUBSTRATE GLASS USING DC 93-500 ADHESIVE
11. WELD COPPER/KAPTON INTERCONNECT TO ELECTRICAL CONTACTS OF SOLAR CELL
12. ELECTRICAL TEST AND INSPECT.

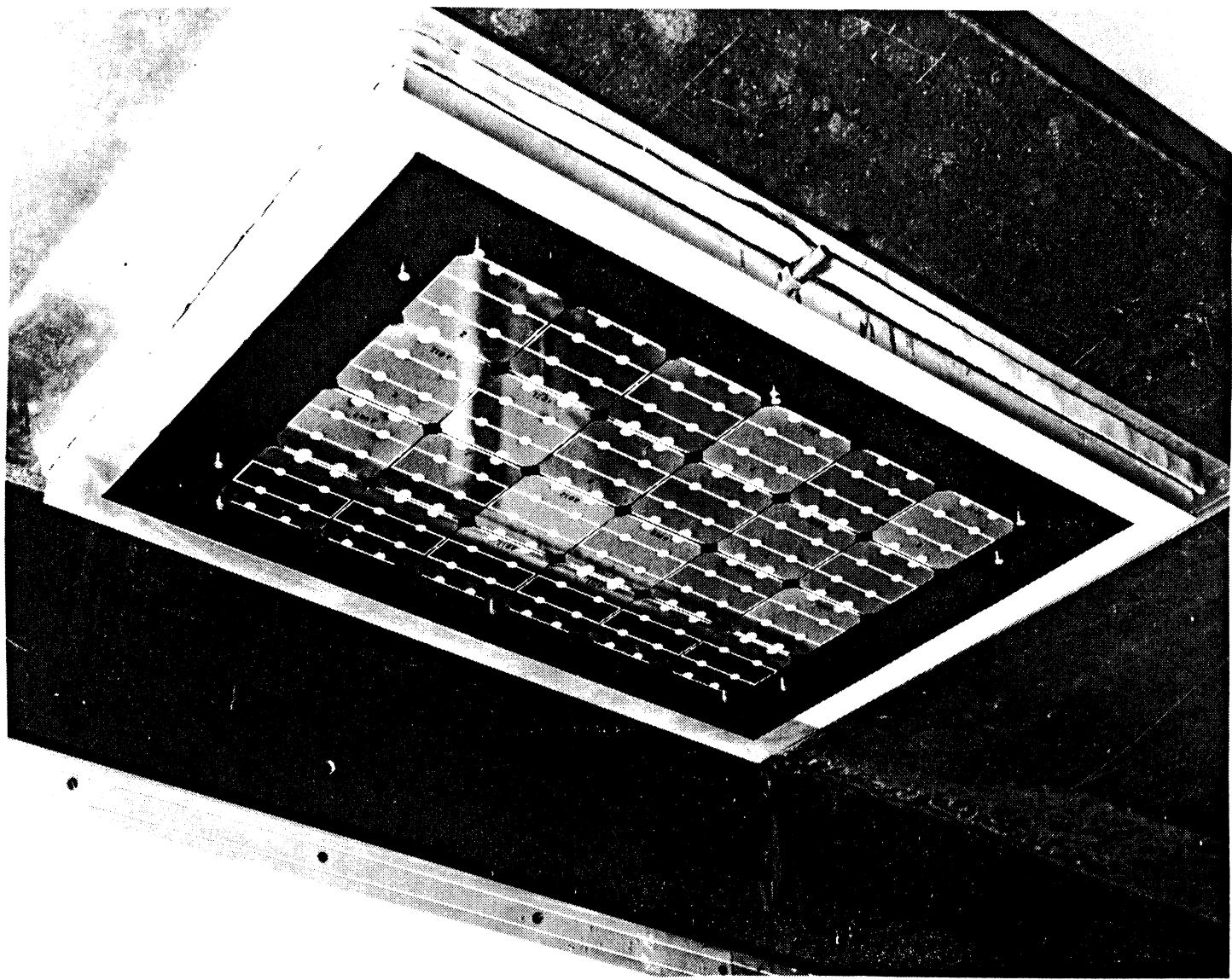
SUPERSTRATE BONDING TOOL



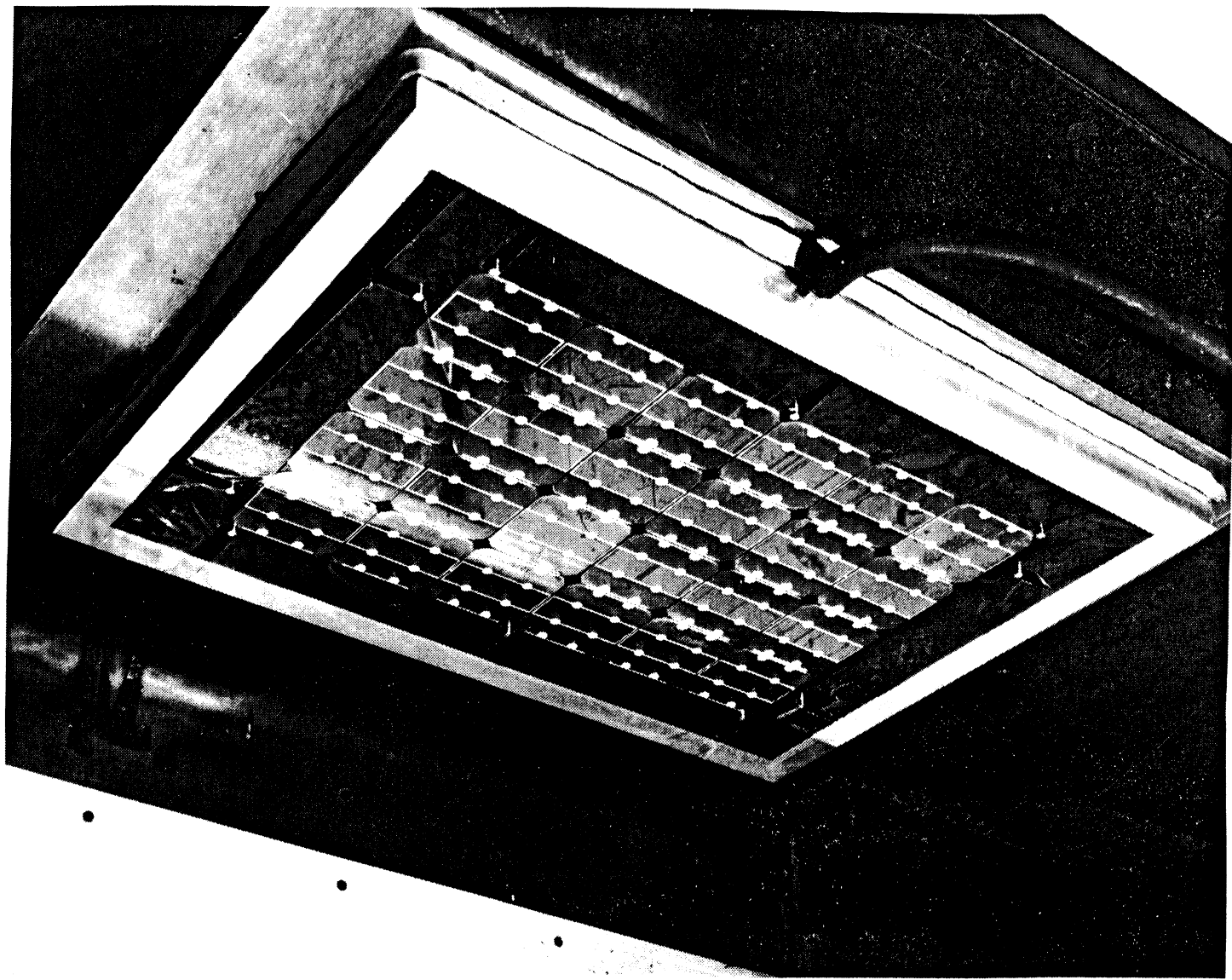
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SOLAR CELLS POSITIONED IN BONDING TOOL

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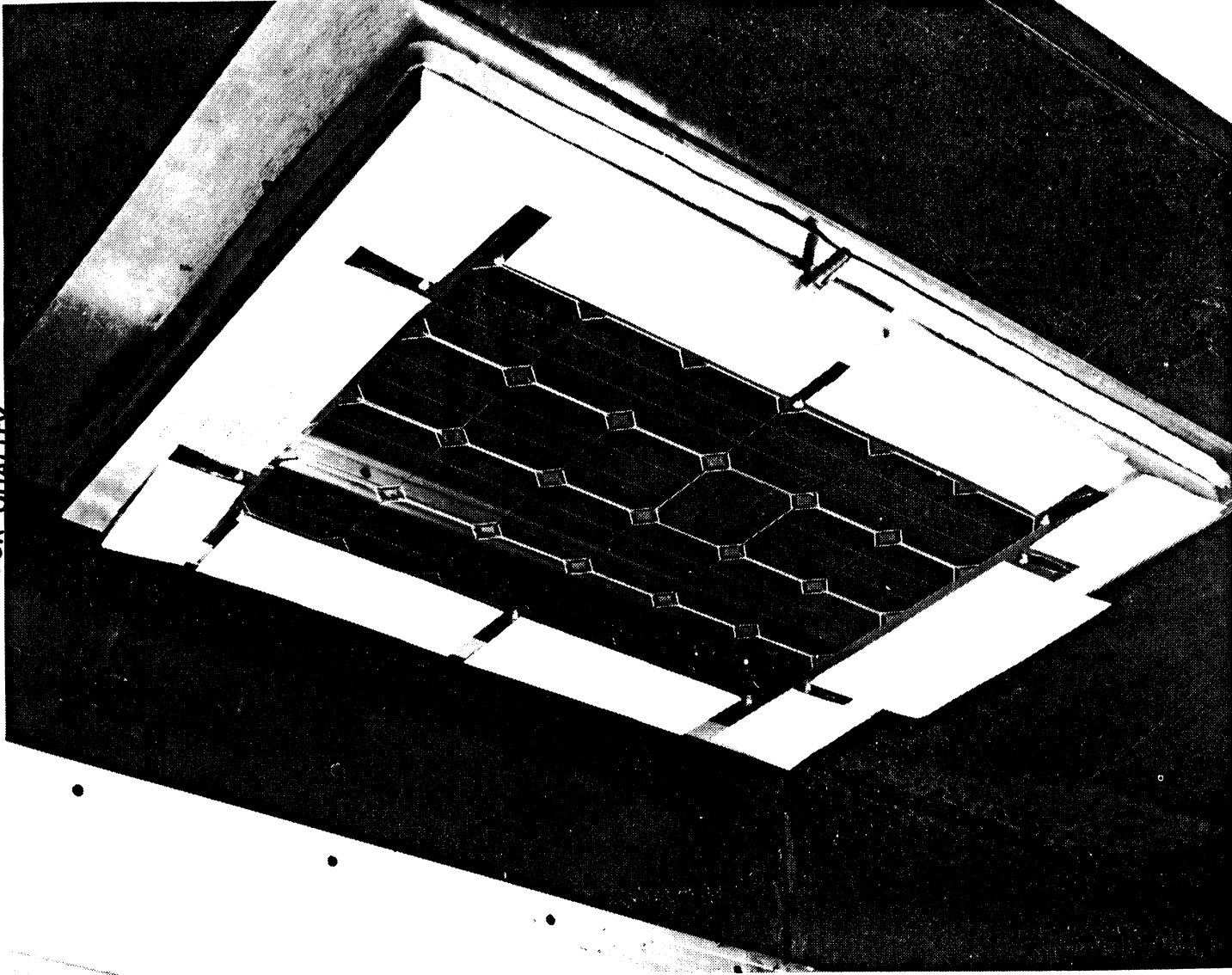


MASKED SOLAR CELLS USING LOW TACK TAPE

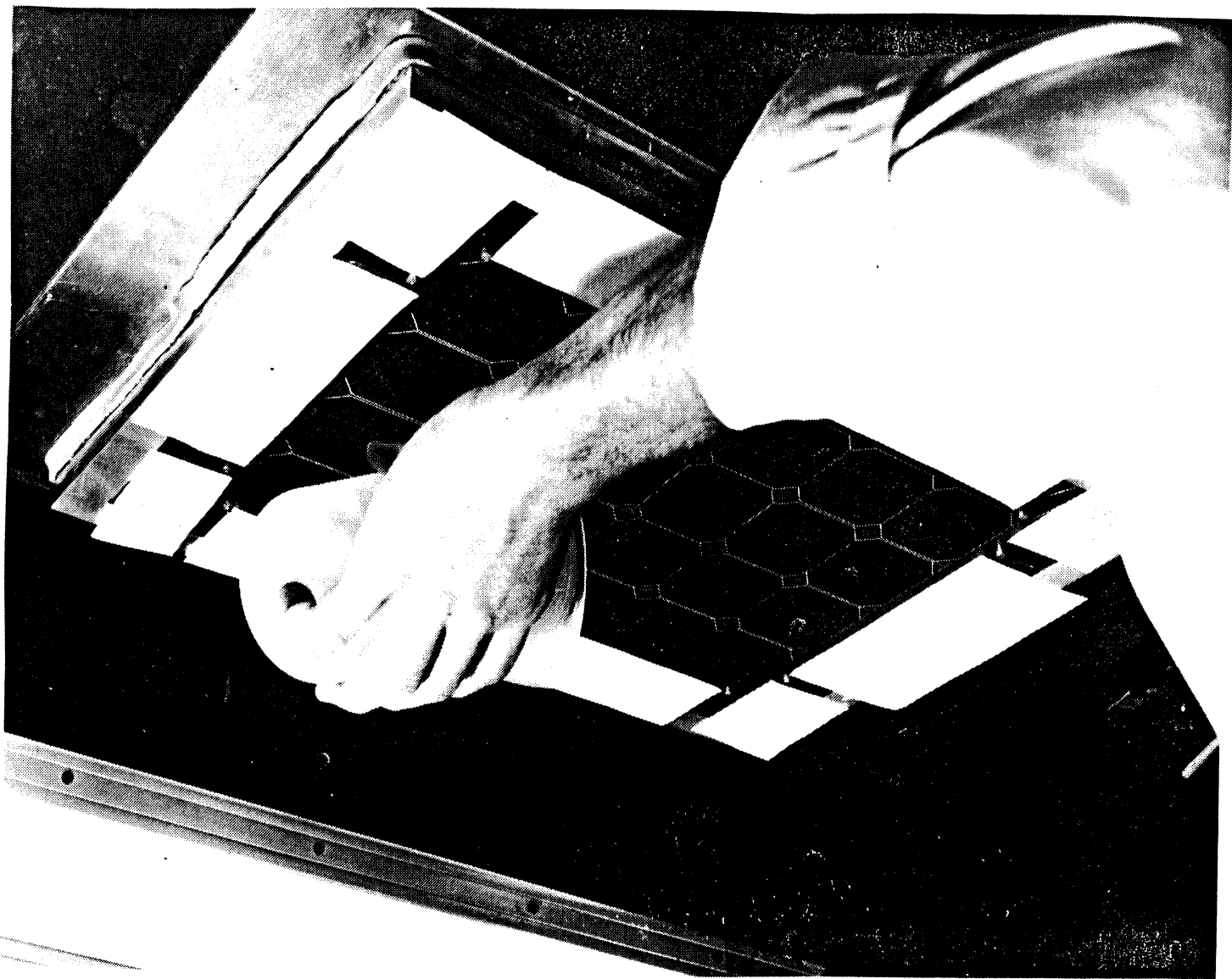


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SOLAR CELLS FACE UP IN BONDING TOOL

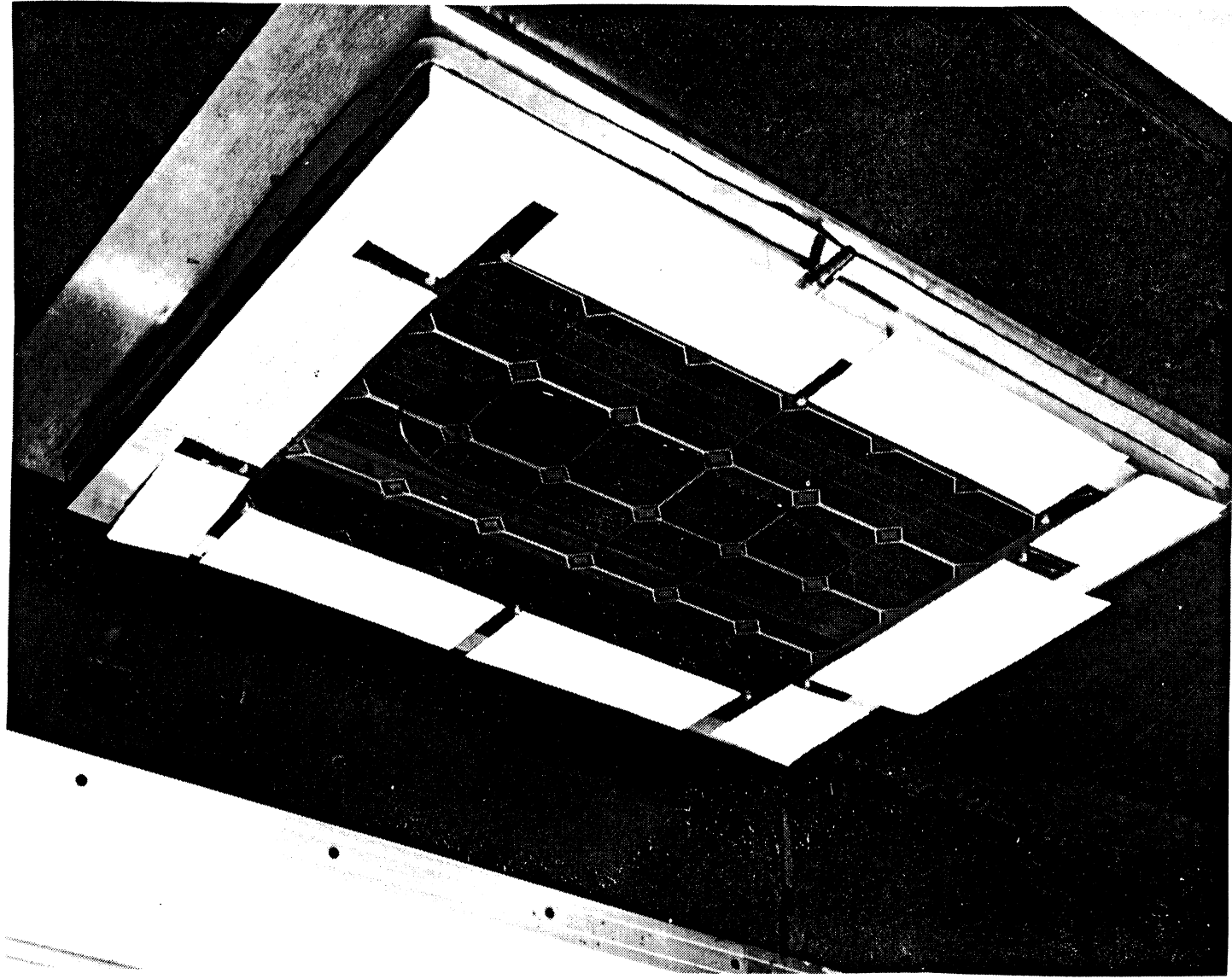


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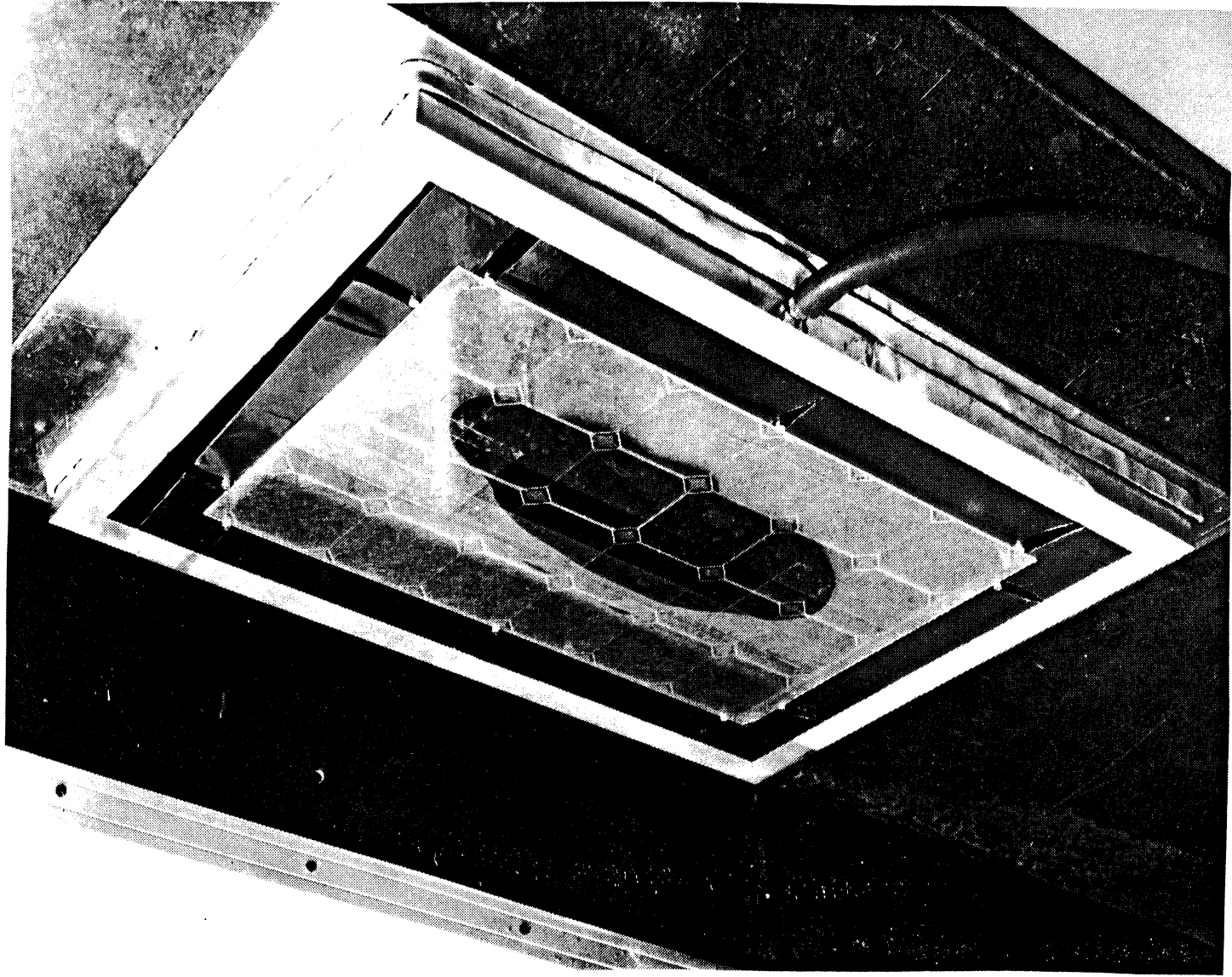
APPLY DC 93-500 ADHESIVE TO SOLAR CELLS

INITIAL APPLICATION OF DC 93-500 ADHESIVE

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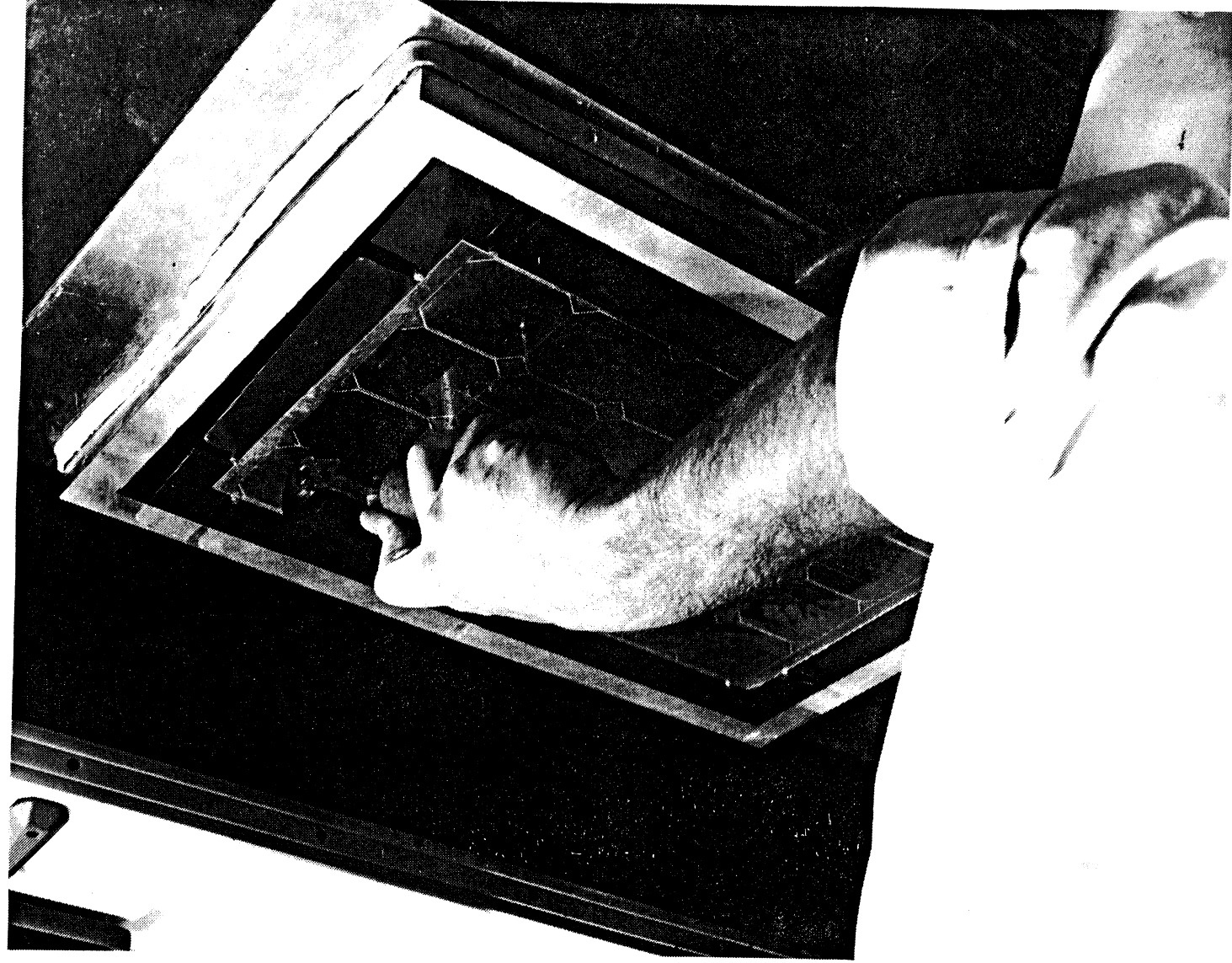
**SUPERSTRATE GLASS WITH PRE CURED SCRIM CLOTH
POSITIONED OVER SOLAR CELLS**



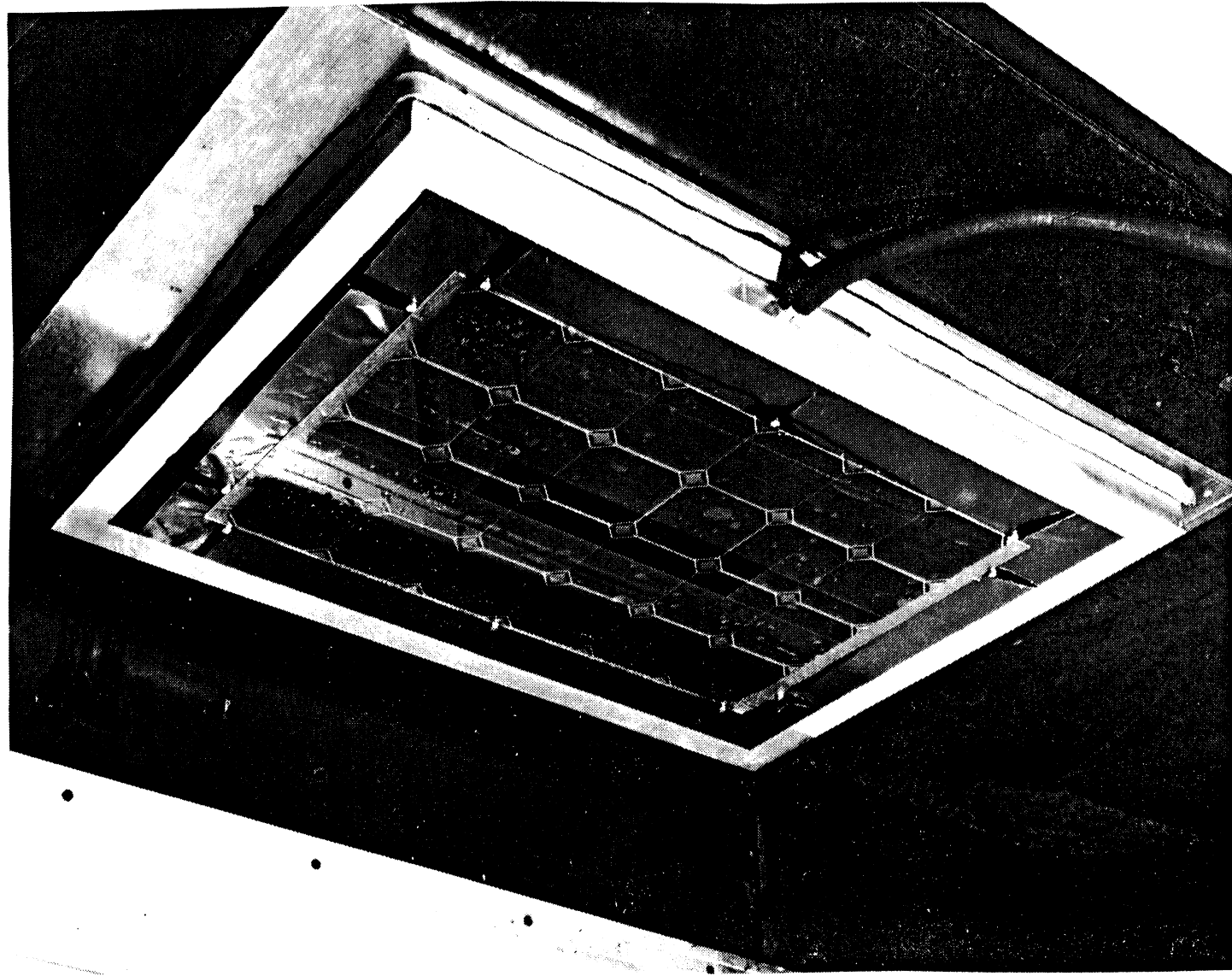
**CRACKING CELL IS
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DISTRIBUTE ADHESIVE USING ROLLER

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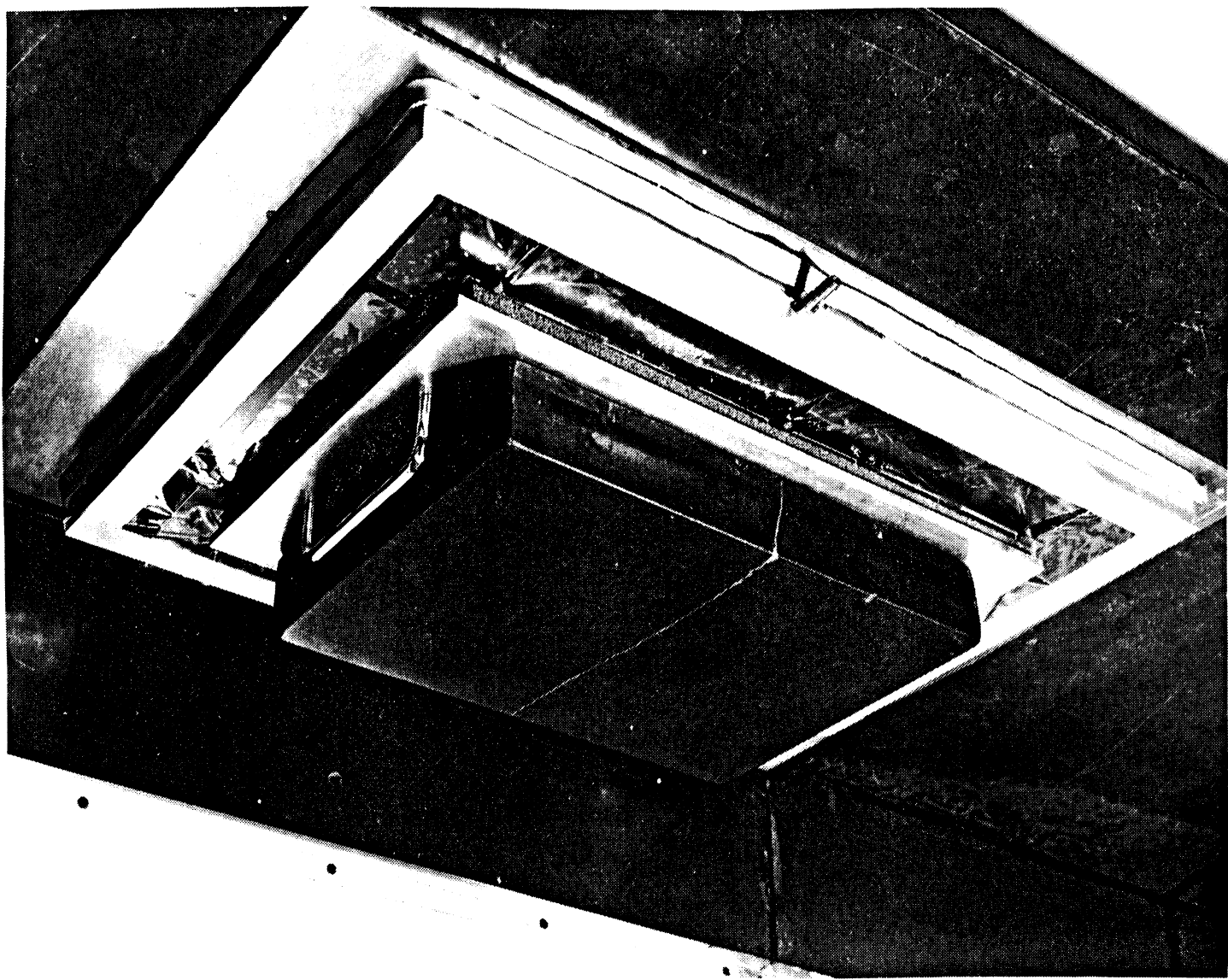
SUPERSTRATE ASSEMBLY WITH ADHESIVE EVENLY DISTRIBUTED

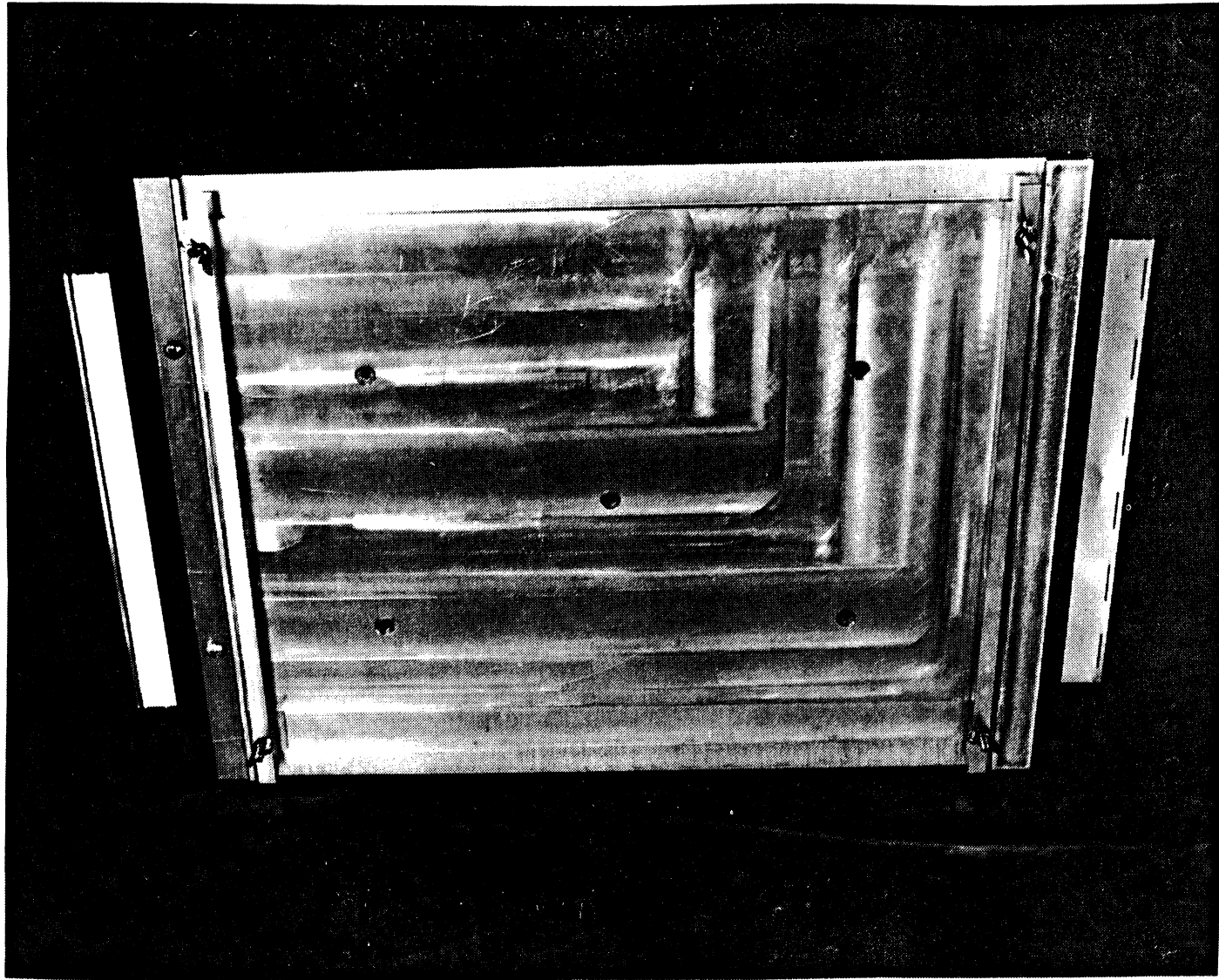


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**WEIGHT PLACED ON SUPERSTRATE ASSEMBLY
BEFORE OVEN CURE**

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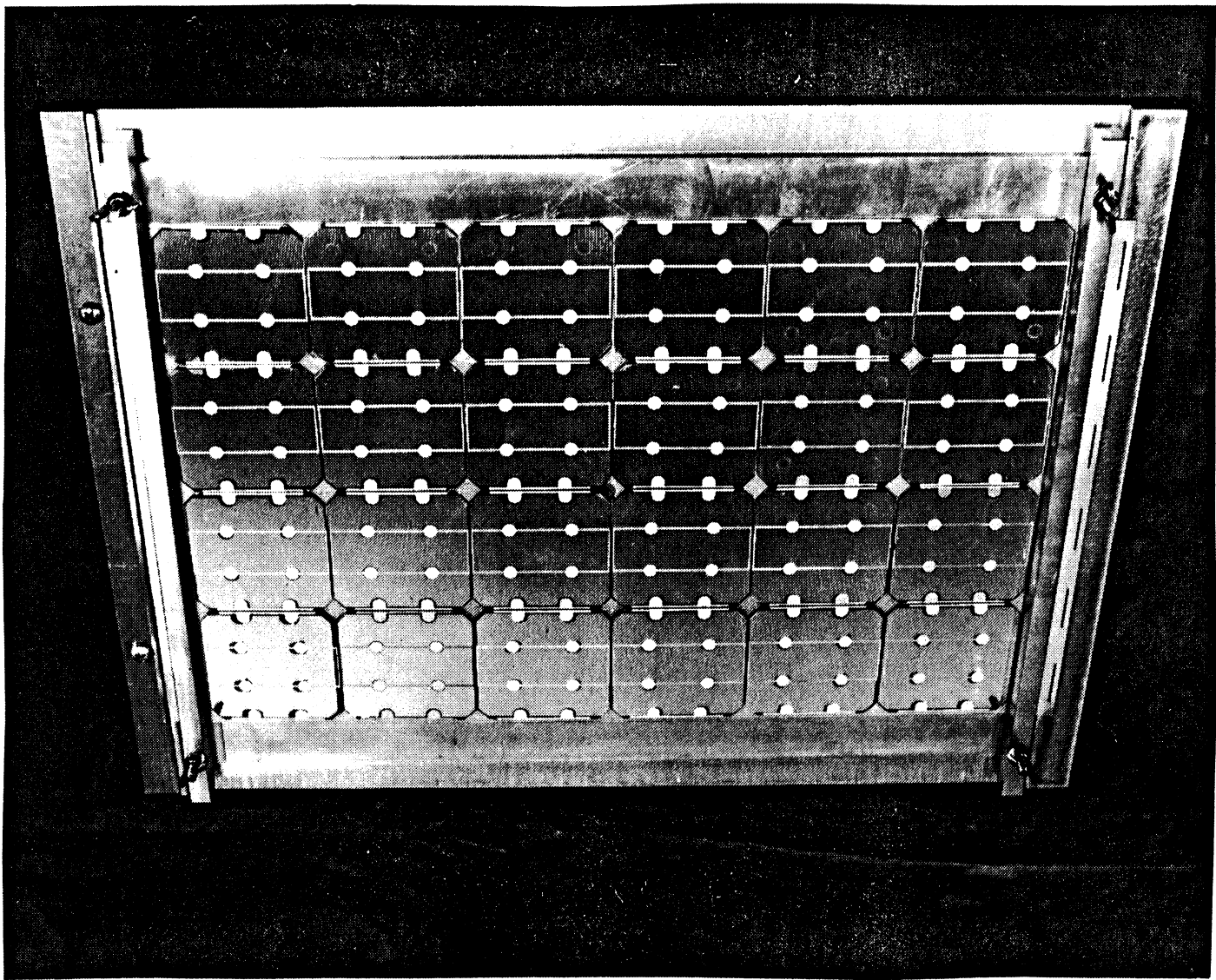


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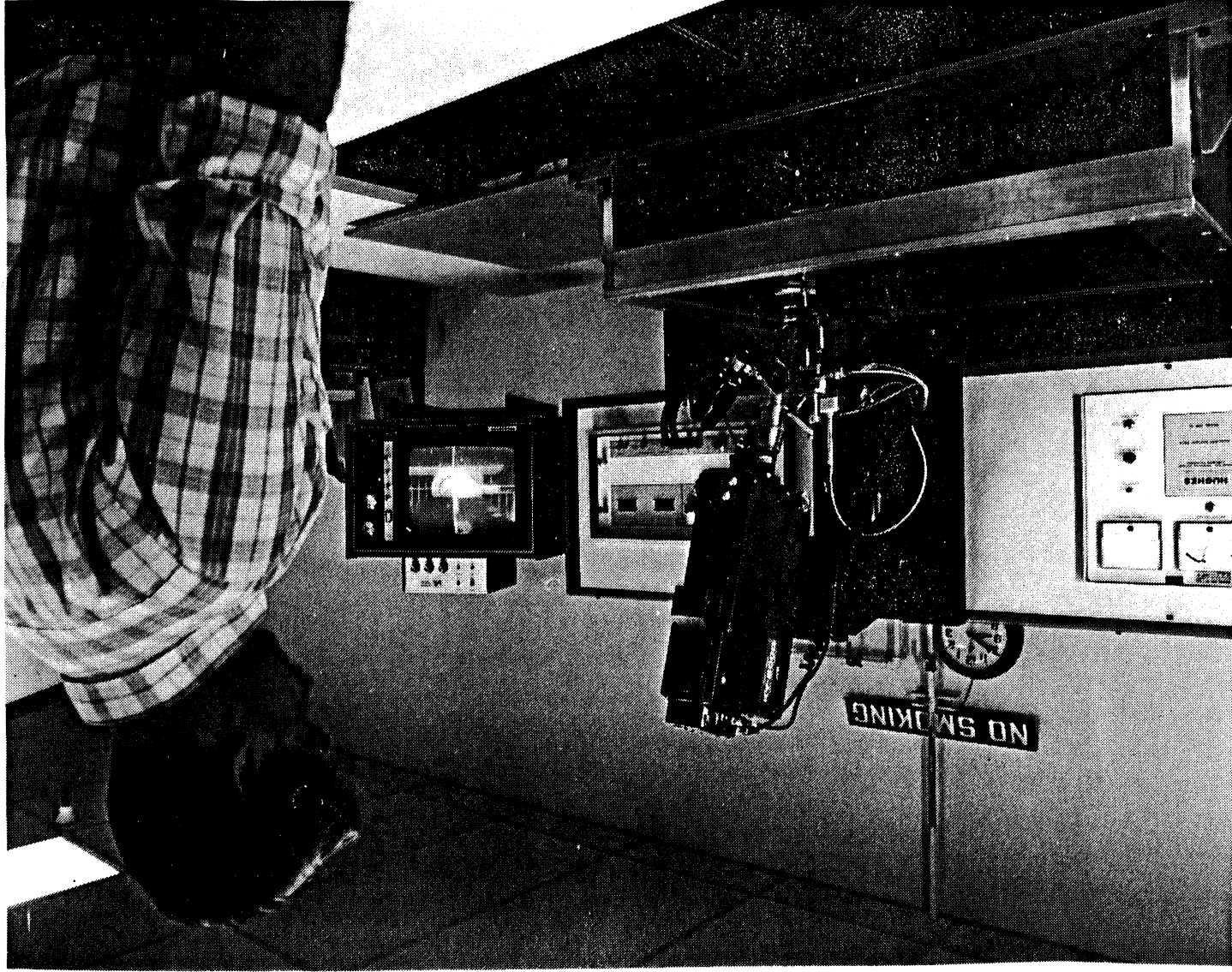
HINGE BONDING TOOL

SUPERSTRATE ASSEMBLY POSITIONED IN BONDING TOOL

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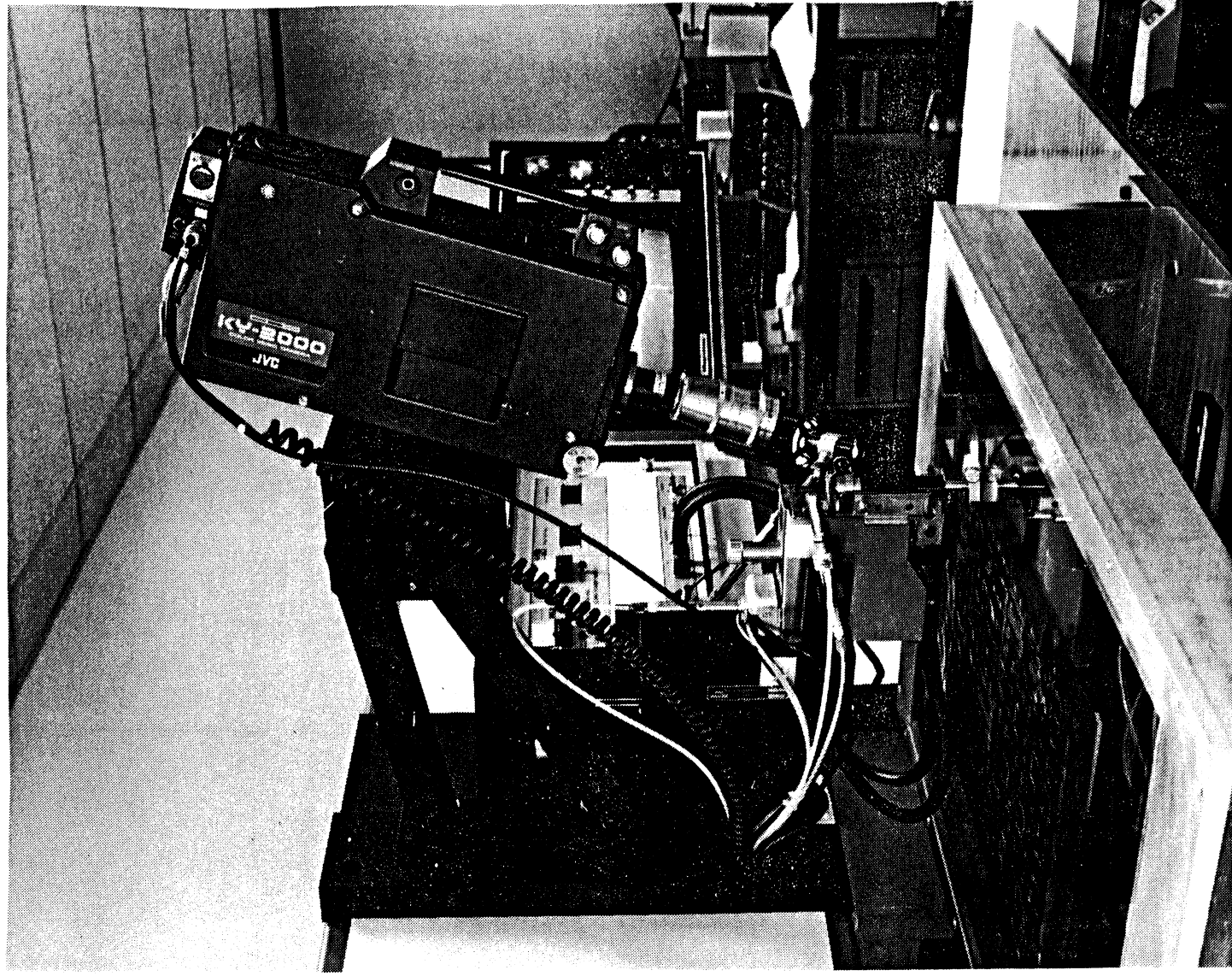


WELDER SET UP FOR WELDING SUPERSTRATE ASSEMBLY



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**WELDING OF COPPER/KAPTON INTERCONNECT
TO SUPERSTRATE ASSEMBLY**



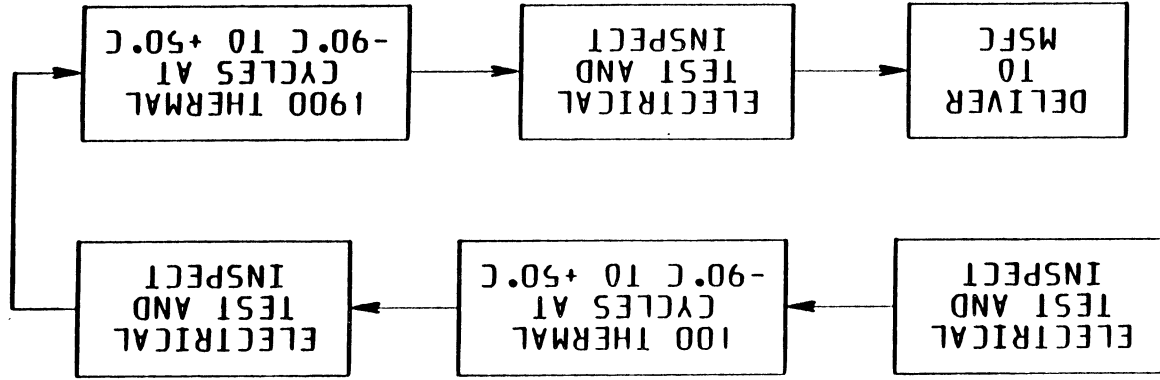
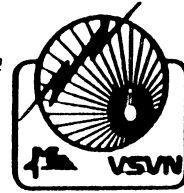
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MODULE FABRICATION BREAKDOWN

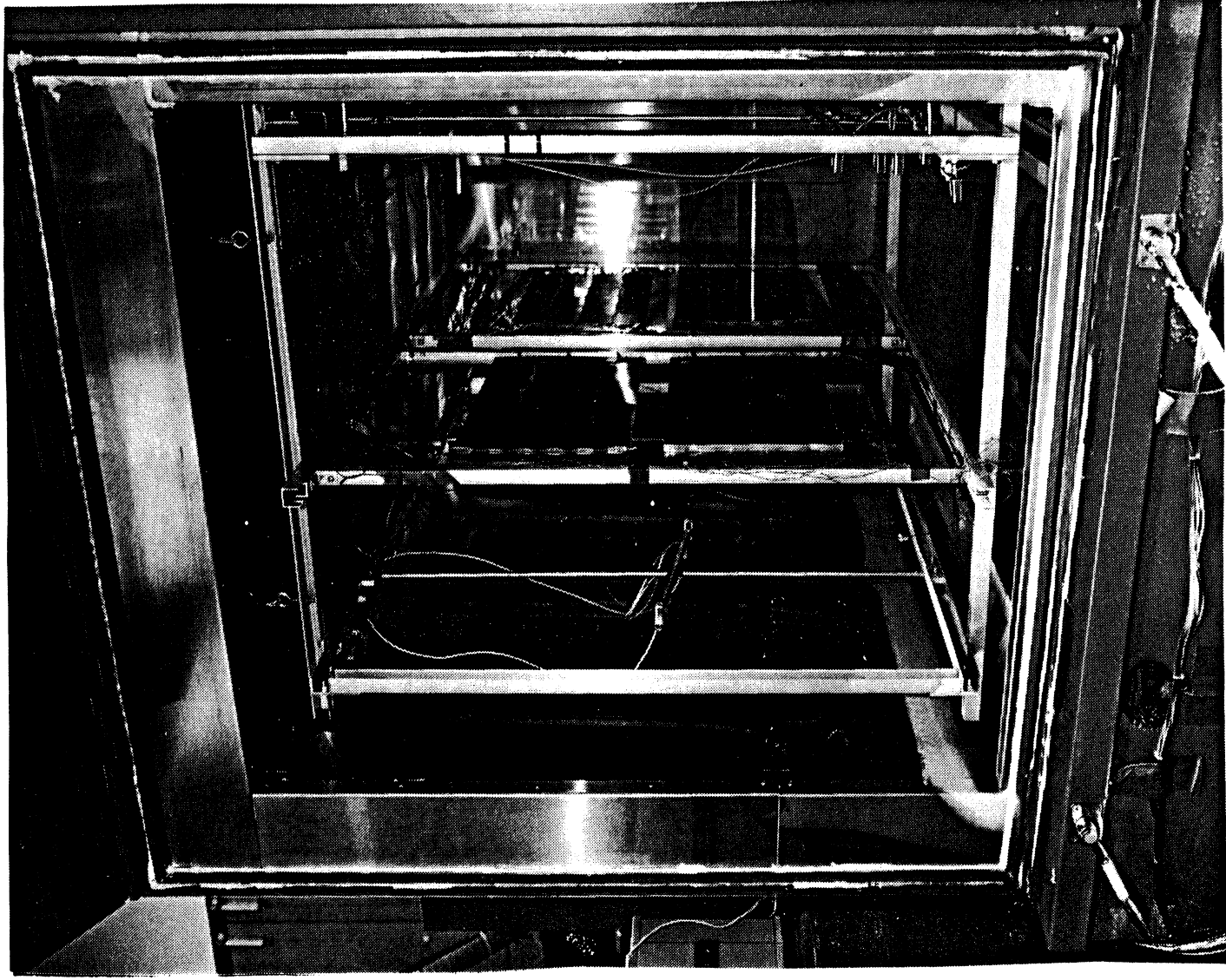


ITEM	USE	NUMBER OF 24-CELL MODULES (SUPERSTRATE) (CONVENTIONAL)
1 PANEL SEGMENT (GOOD ELECTRICAL)	THERMAL CYCLE AT MSFC	5
4 MODULES (GOOD ELECTRICAL)	THERMAL CYCLE AT LMSC	3
3 MODULES (GOOD ELECTRICAL)	THERMAL BALANCE AT BOEING	2
TOTAL 24-CELL MODULES:		10
		2

MODULE THERMAL CYCLE TEST SEQUENCE

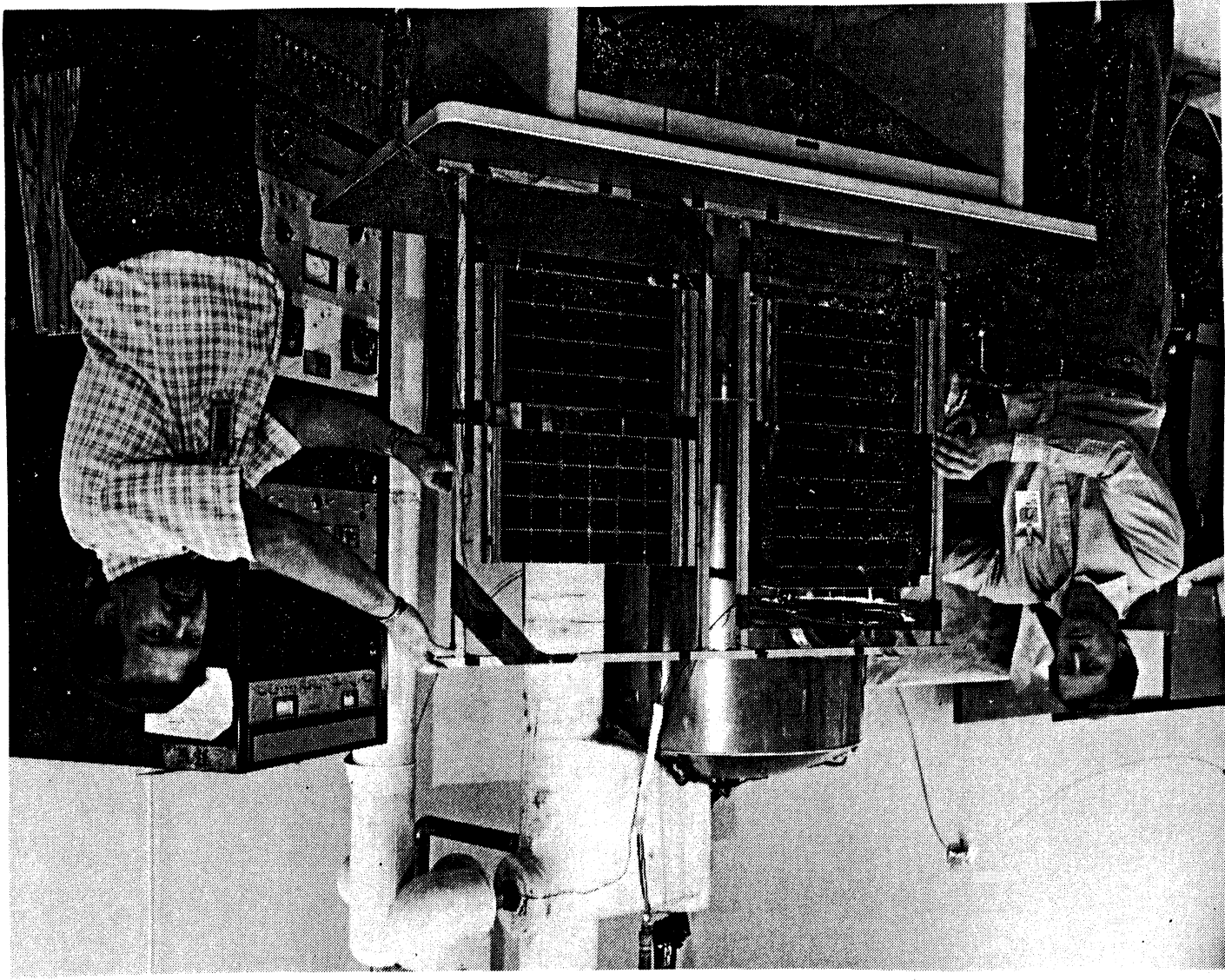


THERMAL CYCLE TEST SETUP - FRONT SIDE



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THERMAL CYCLE SAMPLES - FRONT SIDE



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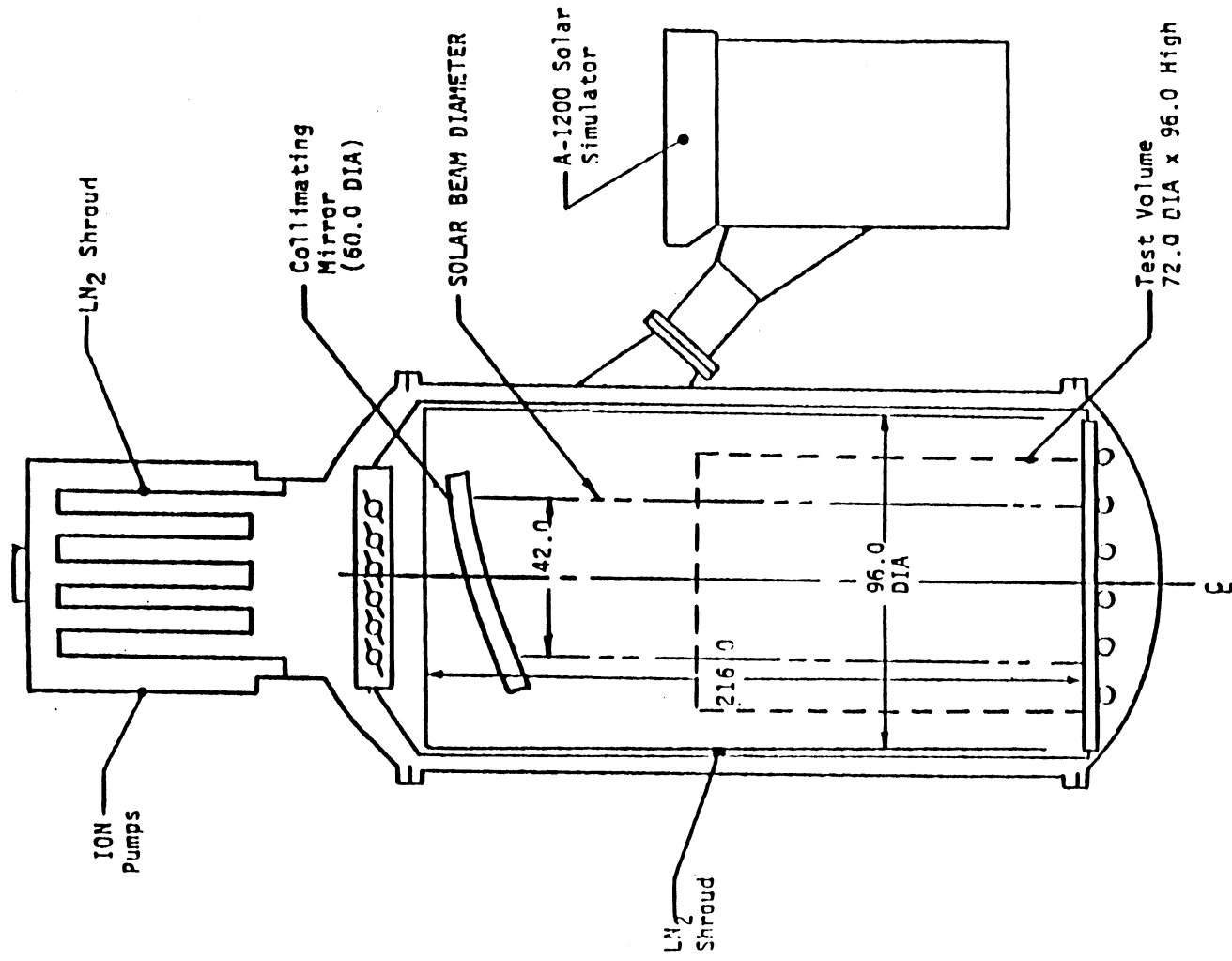
THERMAL BALANCE TESTING OBJECTIVES

- **VERIFY PREDICTED PERFORMANCE OF IR TRANSPARENT SOLAR ARRAY MODULES IN A LOW EARTH ORBIT**
- **DEMONSTRATE IMPROVED THERMAL PERFORMANCE OF IR TRANSPARENT MODULES OVER CONVENTIONAL MODULES**

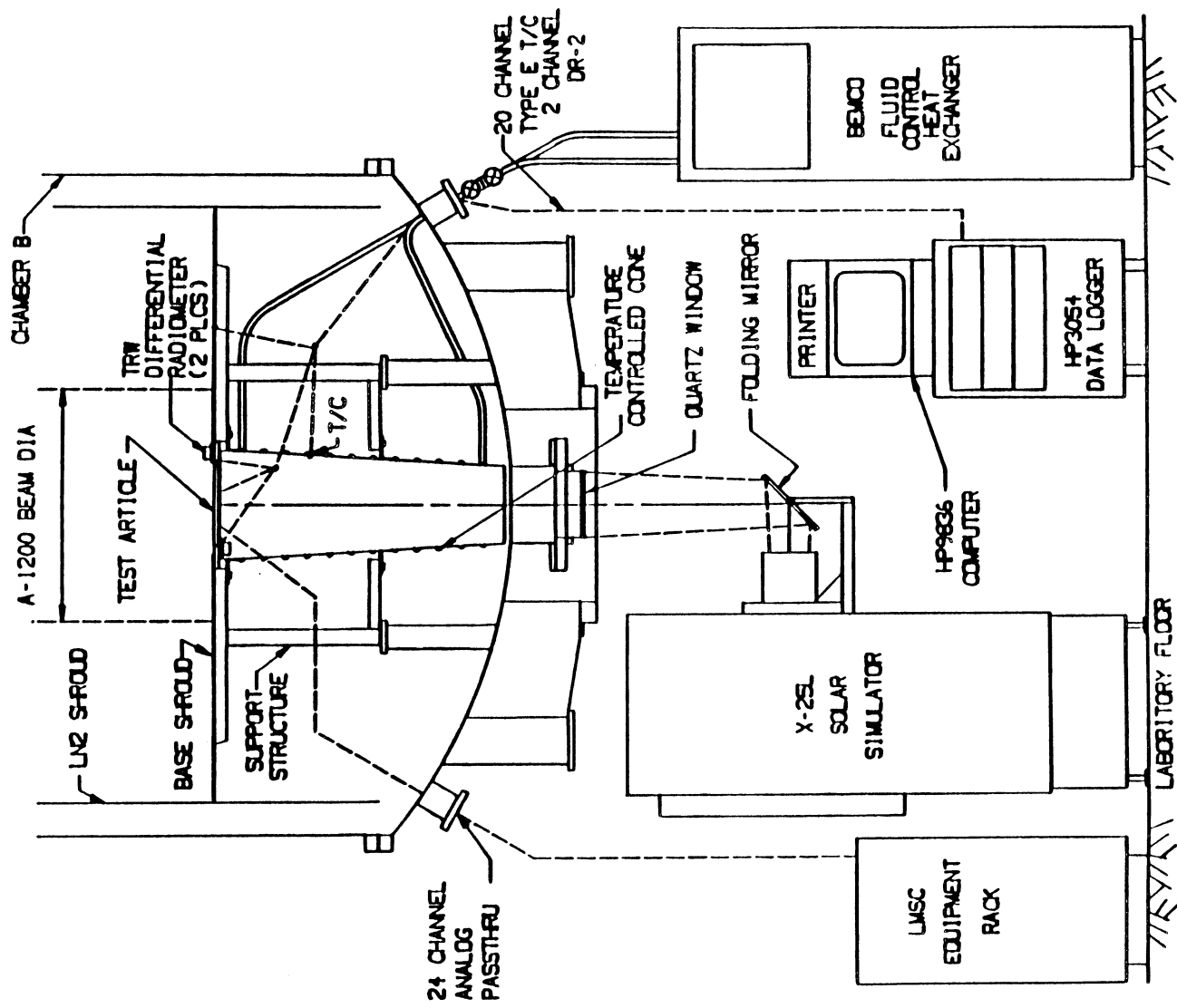
BOEING SPACE CHAMBER B

- THERMAL VACUUM CHAMBER EQUIPPED WITH SOLAR AND ALBEDO SIMULATING LAMPS
 - A1200 SOLAR SIMULATOR
 - X25L ALBEDO SIMULATOR
 - FLUXES UNIFORM ACROSS TEST MODULES ($\pm 5\%$)
 - COLLIMATION ANGLE > 2 DEGREES
- PRESSURE $> 10^{-5}$ TORR
- - 300 F LN₂ COLDWALL
- TEMPERATURE CONTROLLED CONE SIMULATES EARTH IR

SPACE CHAMBER B



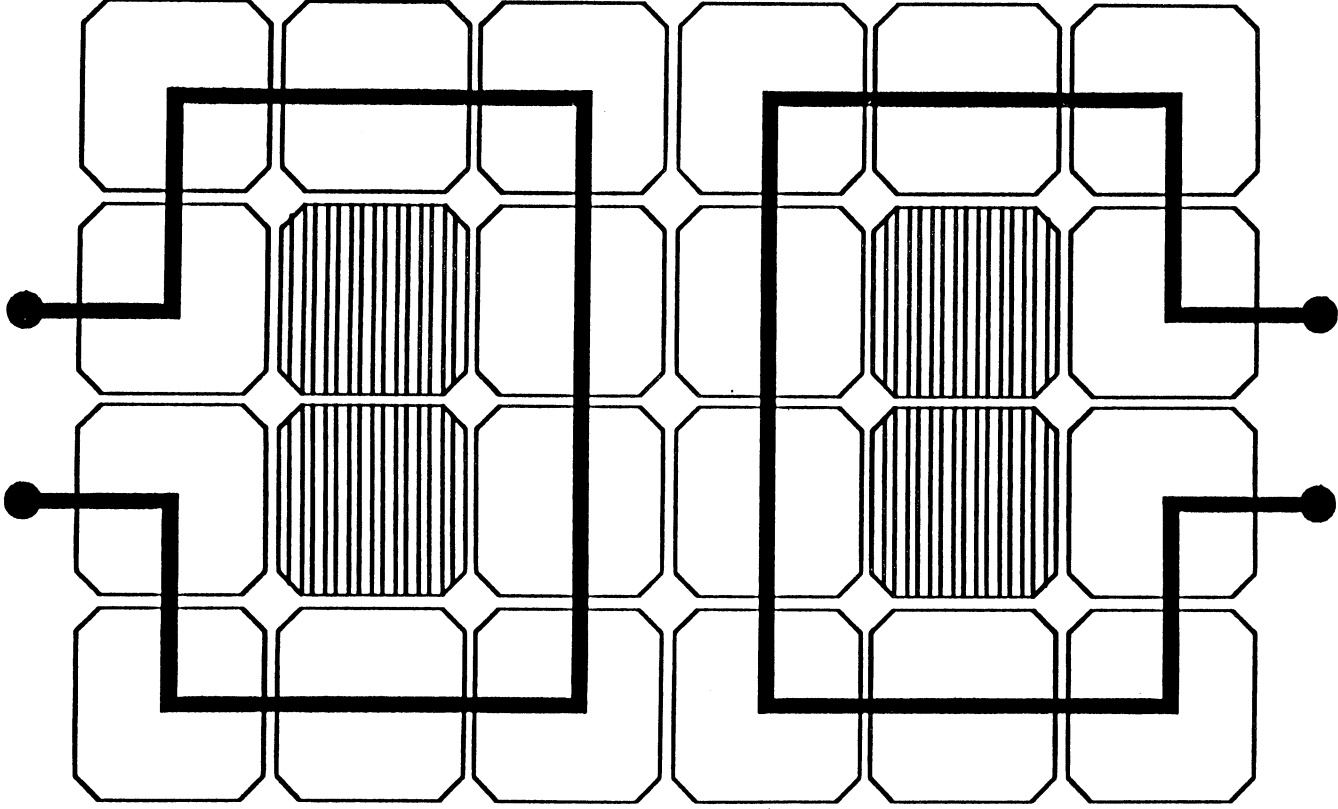
TEST SETUP



SOLAR ARRAY TEST MODULES

- 24 CELLS ARRANGED IN A 6X4 MATRIX
- 3 MODULES FABRICATED AND TESTED
- CONVENTIONAL OPAQUE MODULE
 - BACK SURFACE REFLECTING CELLS
 - FULL KAPTON SUBSTRATE
- IR TRANSPARENT MODULE WITH FULL KAPTON SUBSTRATE
 - GRIDDED BACK SURFACE CELLS
 - SELECTIVELY TRANSMITS WAVELENGTHS BEYOND 1 MICRON
- IR TRANSPARENT MODULE WITH CUTAWAY SUBSTRATE
 - 60% OF KAPTON SUBSTRATE CUTAWAY
- NO BONDING BETWEEN CELL AND SUBSTRATE

SOLAR CELL ELECTRICAL CIRCUITS



FOUR CELLS INDIVIDUALLY CONTROLLED

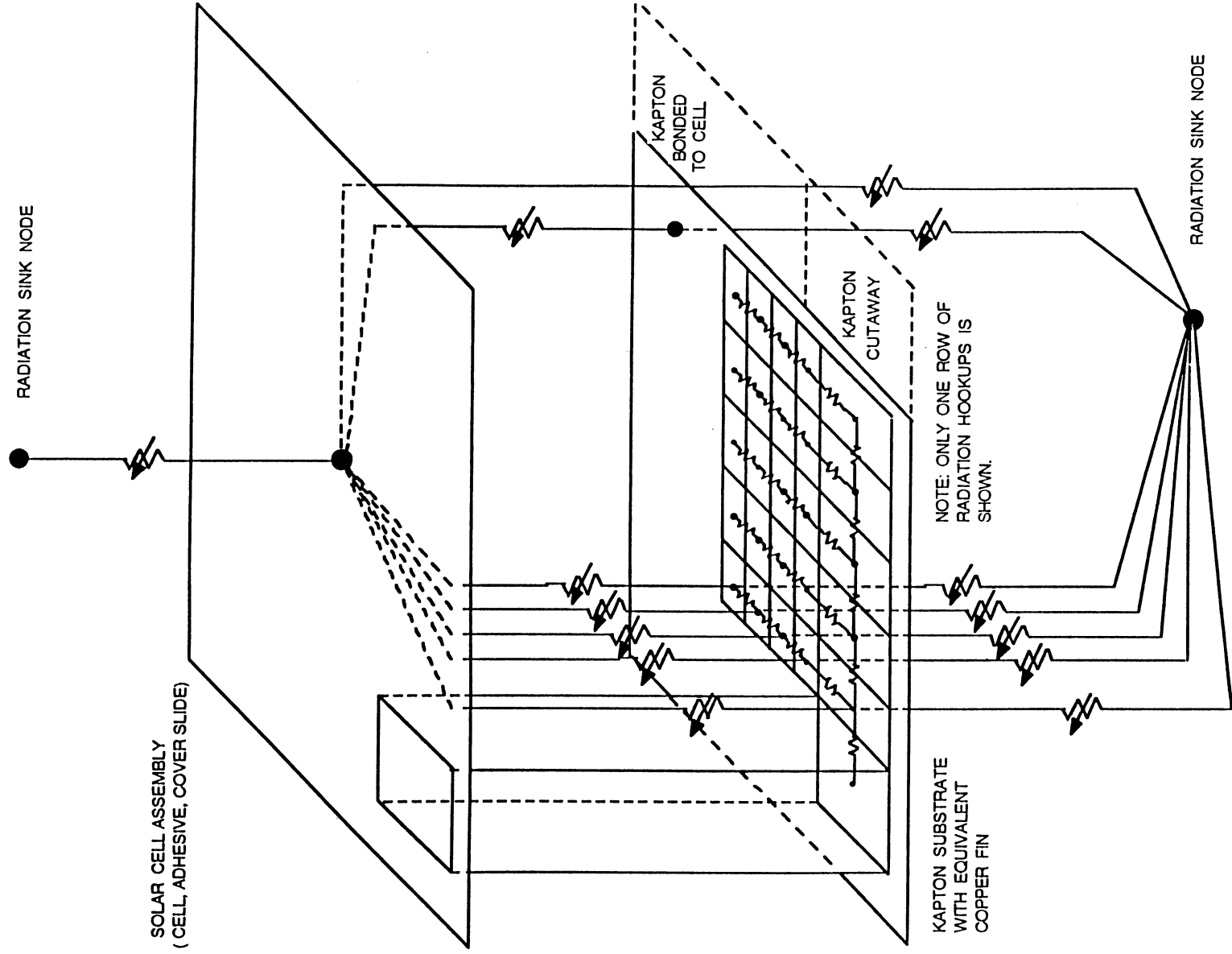
THERMAL BALANCE TESTING

- FIVE TEST CONDITIONS FOR EACH OF THE THREE TEST MODULES
 - 0.97 SOLAR
 - 1.03 SOLAR
 - 1.00 SOLAR
 - 1.00 SOLAR, 0.30 ALBEDO
 - 1.00 SOLAR, 0.40 ALBEDO
- SEVERAL ELECTRICAL POWER SETTINGS FOR EACH TEST CONDITION
 - OPEN CIRCUIT
 - RESISTANCE SETTINGS TO BOUND MAXIMUM POWER POINT
- TEMPERATURES AND CELL POWER DATA RECORDED AT 1 MINUTE INTERVALS

THERMAL MODELLING

- ONLY ONE CELL MODELLED
 - SOLAR AND ALBEDO FLUXES UNIFORM OVER TEST MODULE
 - HIGH THERMAL RESISTANCE BETWEEN CELLS
 - SIMILAR VIEW FACTORS TO CHAMBER SURFACES
- NEGLECT CONDUCTION LOSSES FROM TEST MODULES
- RADIATION NETWORK CREATED BY COMPUTER MODELLING OF CHAMBER SURFACES
- ELECTRICAL POWER SUBTRACTED FROM TOTAL ABSORBED HEAT
- THERMAL SURFACE PROPERTIES OF ARRAY MATERIALS INTEGRATED WITH RESPECT TO SOLAR AND ALBEDO SIMULATORS' SPECTRAL DISTRIBUTIONS OF ENERGY
- ABSORBED HEAT LOAD INCLUDES SECONDARY TERMS DUE TO REFLECTION AND TRANSMISSION OF ENERGY WITHIN MODULE

CELL THERMAL MODEL



THERMAL SURFACE PROPERTIES

MATERIAL	SUN			A1200			X25L		
	α	ρ	τ	α	ρ	τ	α	ρ	τ
OPAQUE CELL ASSEMBLY FRONTFACE (CELL, ADHESIVE, COVERSLIDE)	0.68	0.32	0.0	0.72	0.28	0.0	-	-	-
OPAQUE CELL ASSEMBLY BACKFACE (CELL, ADHESIVE, COVERSLIDE)	0.08	0.92	0.0	-	-	-	0.08	0.92	0.0
TRANSPARENT CELL ASSEMBLY FRONTFACE (CELL, ADHESIVE, SUPERSTRATE)	0.62	0.21	0.17	0.69	0.14	0.17	-	-	-
TRANSPARENT CELL ASSEMBLY BACKFACE (CELL, ADHESIVE, SUPERSTRATE)	0.62	0.21	0.17	-	-	-	0.57	0.30	0.13

SPECTRAL ENERGY DISTRIBUTION MEASUREMENT FOR A-1200



BAND NO.	BANDWIDTH (MICRONS)	MATCHED DATA	NORMALIZED MATCHED DATA TO ONE SOLAR CONSTANT (W/M ²)	ENG STANDARD	% DEVIATION
1	0.25-0.35	4.3	19.9	58.5	-65.9
2	0.35-0.40	13.2	61.2	56.9	7.5
3	0.40-0.45	17.9	83.0	86.8	-4.4
4	0.45-0.50	21.8	101.0	100.9	0.1
5	0.50-0.60	44.7	207.2	177.0	17.1
6	0.60-0.70	38.0	176.1	151.5	16.3
7	0.70-0.80	29.0	134.4	123.7	8.7
8	0.80-0.90	21.5	99.7	99.3	0.4
9	0.90-1.00	16.4	76.0	82.9	-8.3
10	1.00-1.20	25.0	115.9	120.6	-3.9
11	1.20-1.50	22.4	103.8	111.4	-6.8
12	1.50-1.80	14.5	67.2	67.0	0.3
13	1.80-2.20	8.4	38.9	43.8	-11.1
14	2.20-2.50	3.4	15.8	19.8	-20.4
TOTAL					
280.5					
1300.1					
1300.1					

100%
ABSORPTION
IR

SPECTRAL ENERGY DISTRIBUTION MEASUREMENT FOR X-25



BAND NO.	BANDWIDTH (MICRONS)	MATCHED DATA	NORMALIZED MATCHED DATA TO ONE SOLAR CONSTANT (w/m ²)	ENG STANDARD	% DEVIATION
1	0.25-0.35	3.4	17.9	58.5	-69.4
2	0.35-0.40	9.1	47.9	56.9	-15.9
3	0.40-0.45	13.6	71.5	86.8	-17.6
4	0.45-0.50	15.3	80.5	100.9	-20.3
5	0.50-0.60	32.0	168.3	177.0	-4.9
6	0.60-0.70	28.3	148.8	151.5	-1.8
7	0.70-0.80	23.5	123.6	123.7	-0.1
8	0.80-0.90	20.7	108.9	99.3	9.6
9	0.90-1.00	18.2	95.7	82.9	15.5
10	1.00-1.20	27.0	142.0	120.6	17.7
11	1.20-1.50	26.5	139.4	111.4	25.1
12	1.50-1.80	16.2	85.2	67.0	27.2
13	1.80-2.20	9.5	50.0	43.8	14.1
14	2.20-2.50	3.9	20.5	19.8	3.6
TOTAL		247.2	1300.1	1300.1	

100%
ABSORPTION

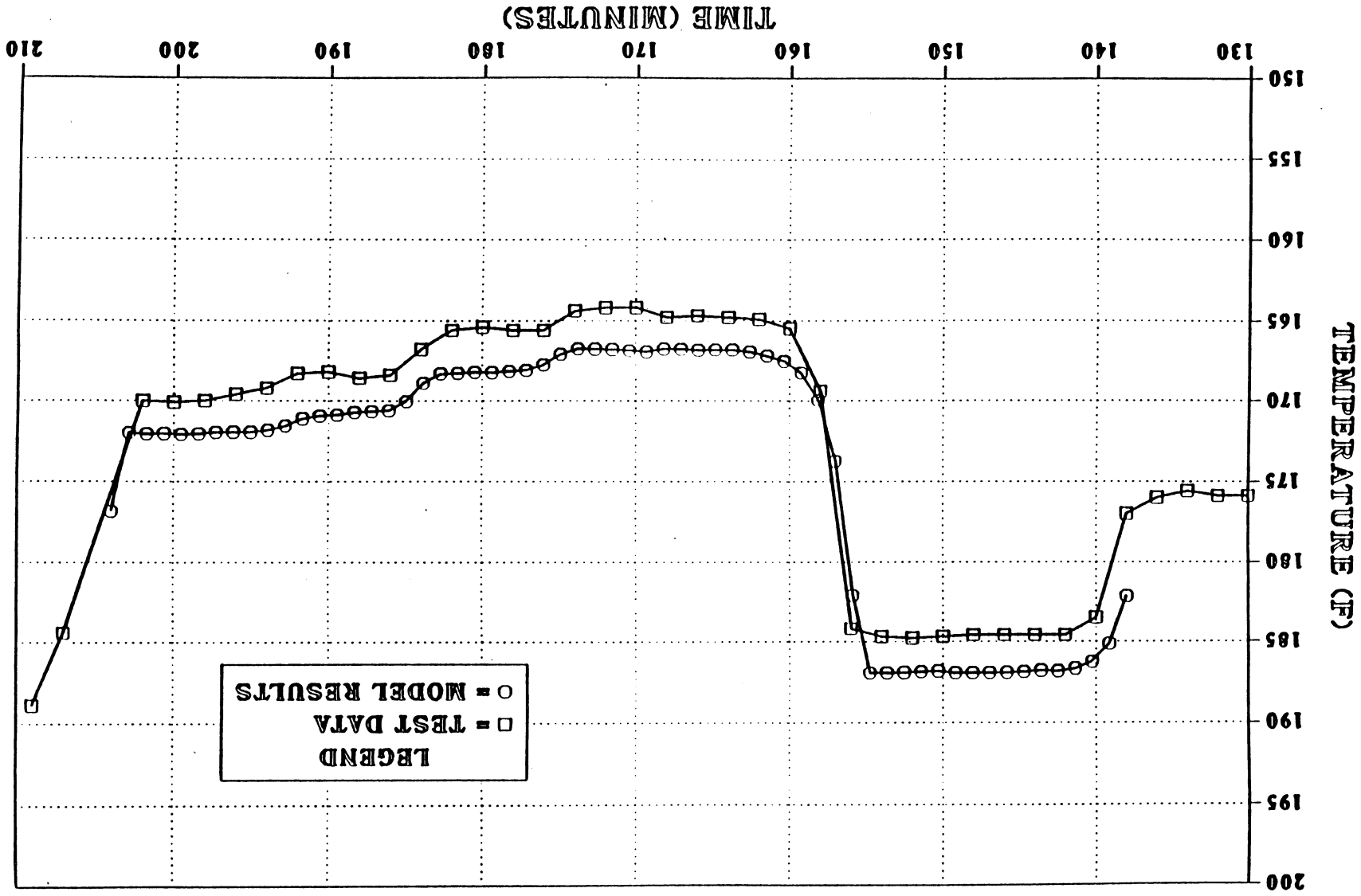
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OPAQUE CELL WITH FULL SUBSTRATE

JULY 23 TESTS

SOLAR=1.0, ALBEDO= 0.0

THERMOCOUPLE #3, POWER CIRCUIT #3



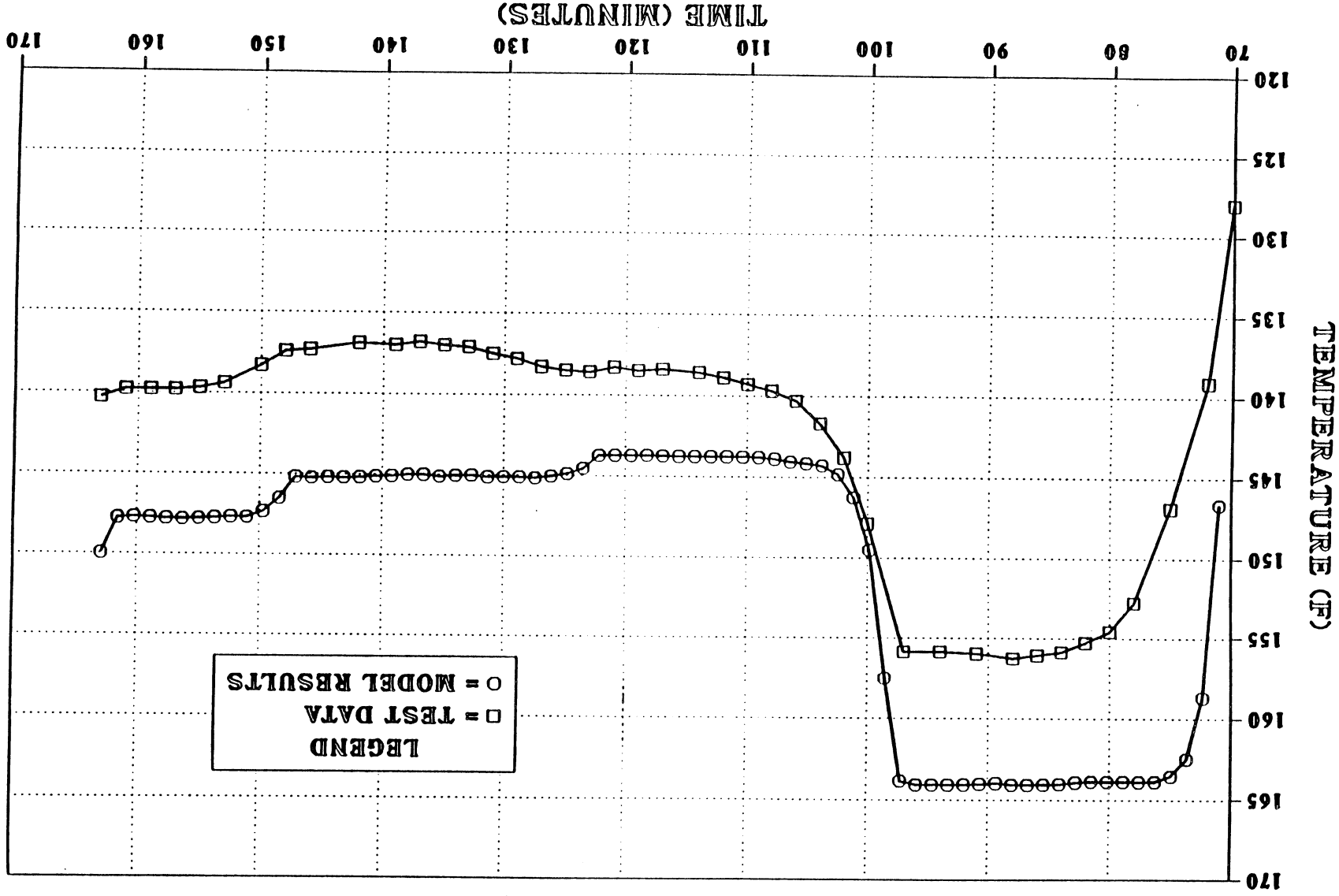
15-APR-87, Thermodynamics

TRANSPARENT CELL WITH FULL SUBSTRATE

JULY 25 TESTS

SOLAR=1.03, ALBEDO=0.0

THERMOCOUPLE #4, POWER CIRCUIT #4

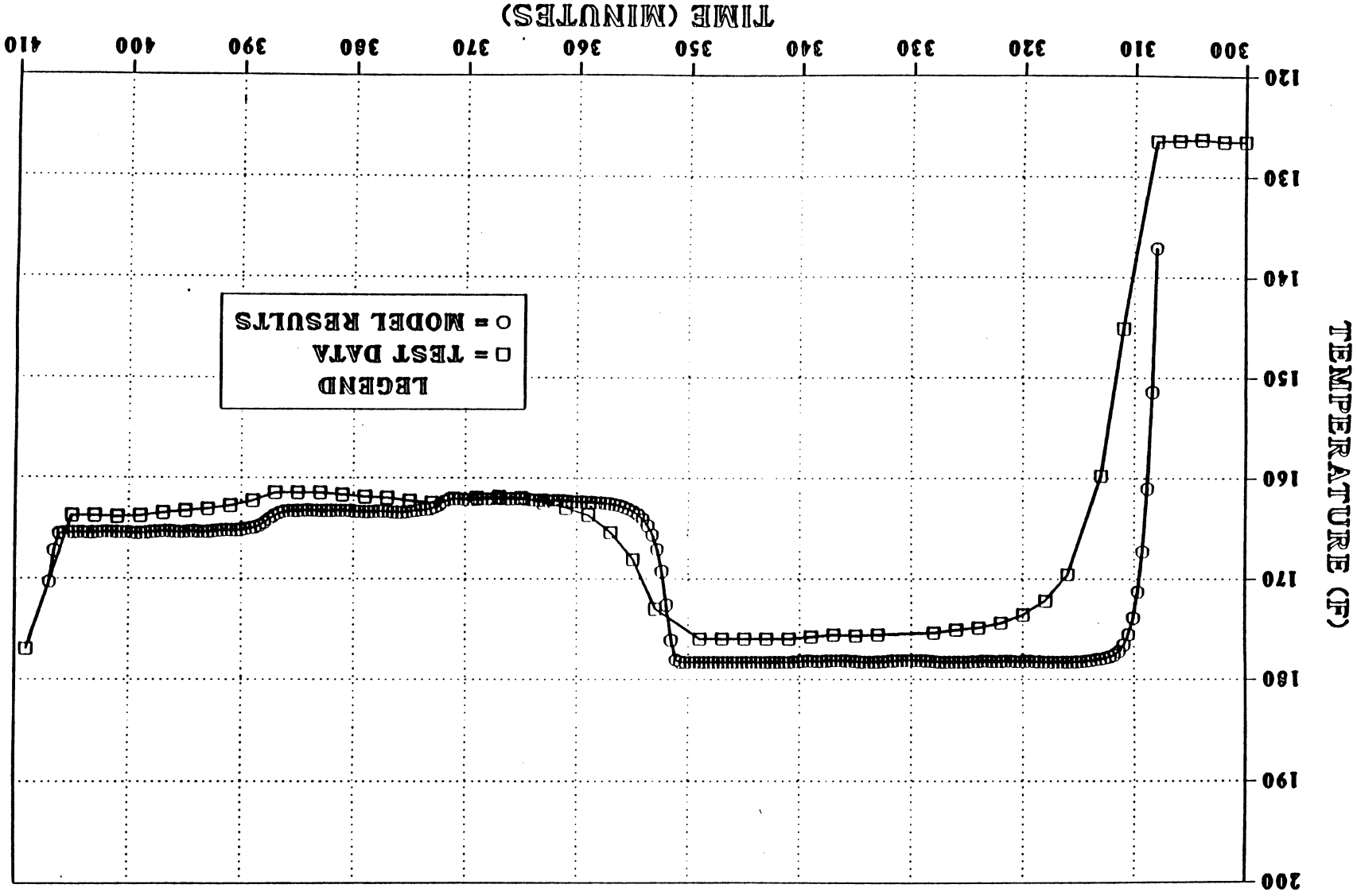


TRANSPARENT CELL WITH CUTAWAY SUBSTRATE

JULY 24 TESTS

SOLAR=1.00, ALBEDO= 0.30

THERMOCOUPLE #3, POWER CIRCUIT #3



15-APR-87, Thermodynamics

CORRELATION BETWEEN MODEL RESULTS AND TEST DATA

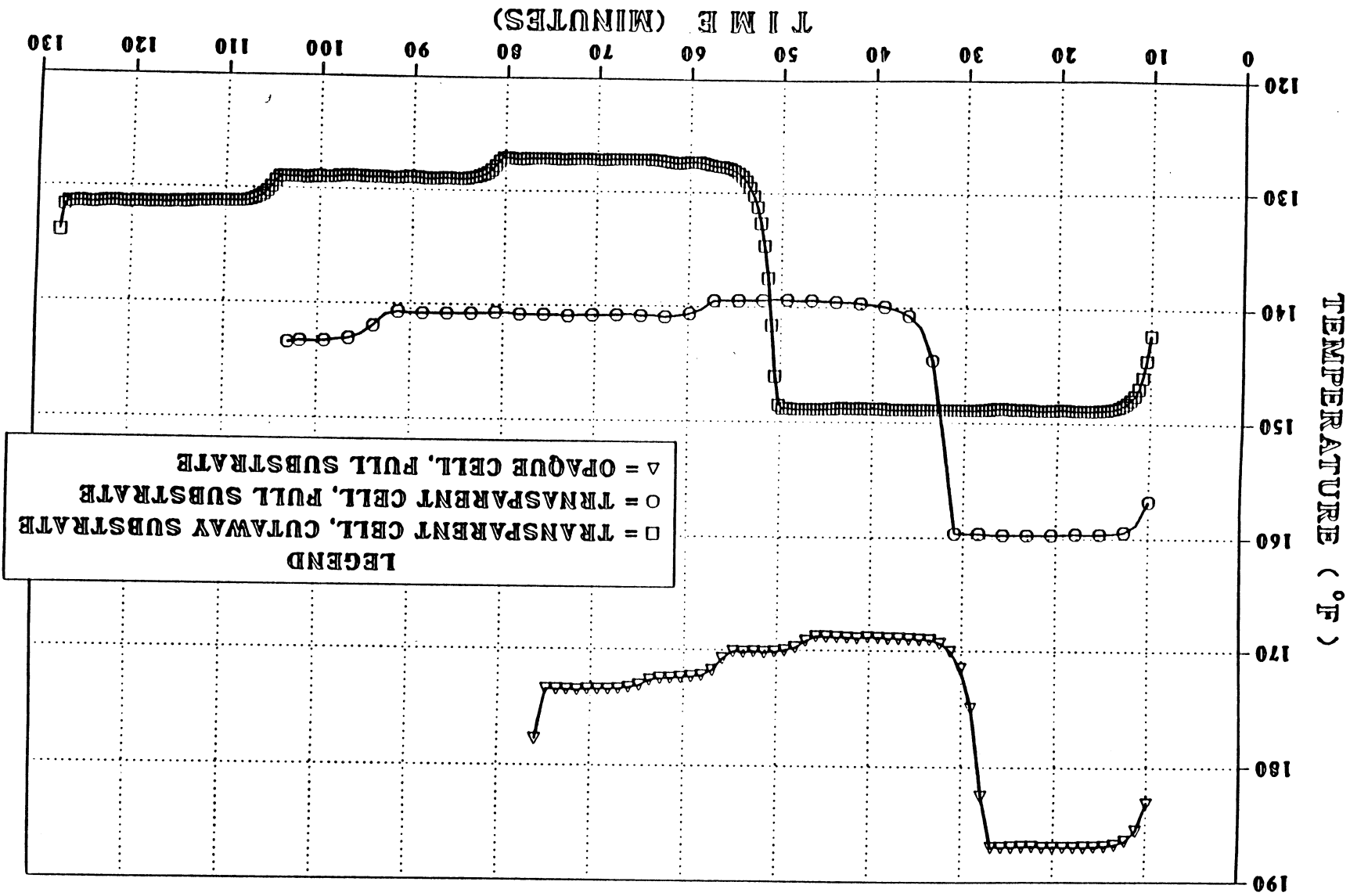
- OPAQUE TEST MODULE
 - MODEL RESULTS AND TEST DATA WITHIN 5 F IN 17 OF 20 CASES AT ALL STEADY STATE CONDITIONS
- TRANSPARENT TEST MODULE WITH FULL SUBSTRATE
 - MODEL RESULTS AND TEST DATA WITHIN 10 F IN 12 OF 15 CASES AT ALL STEADY STATE CONDITIONS
 - MODEL RESULTS WARMER THAN TEST DATA
- TRANSPARENT TEST MODULE WITH CUTAWAY SUBSTRATE
 - MODEL RESULTS AND TEST DATA WITHIN 5 F IN ALL 20 CASES AT ALL STEADY STATE CONDITIONS
 - MODEL RESULTS PREDICT MORE RAPID TRANSIENT RESPONSE THAN TEST DATA SHOWS

PREDICTED SOLAR CELL TEST TEMPERATURES

FOR THREE ARRAY DESIGNS

SOLAR = 1.0, ALBEDO = 0.0

POWER CIRCUIT #2

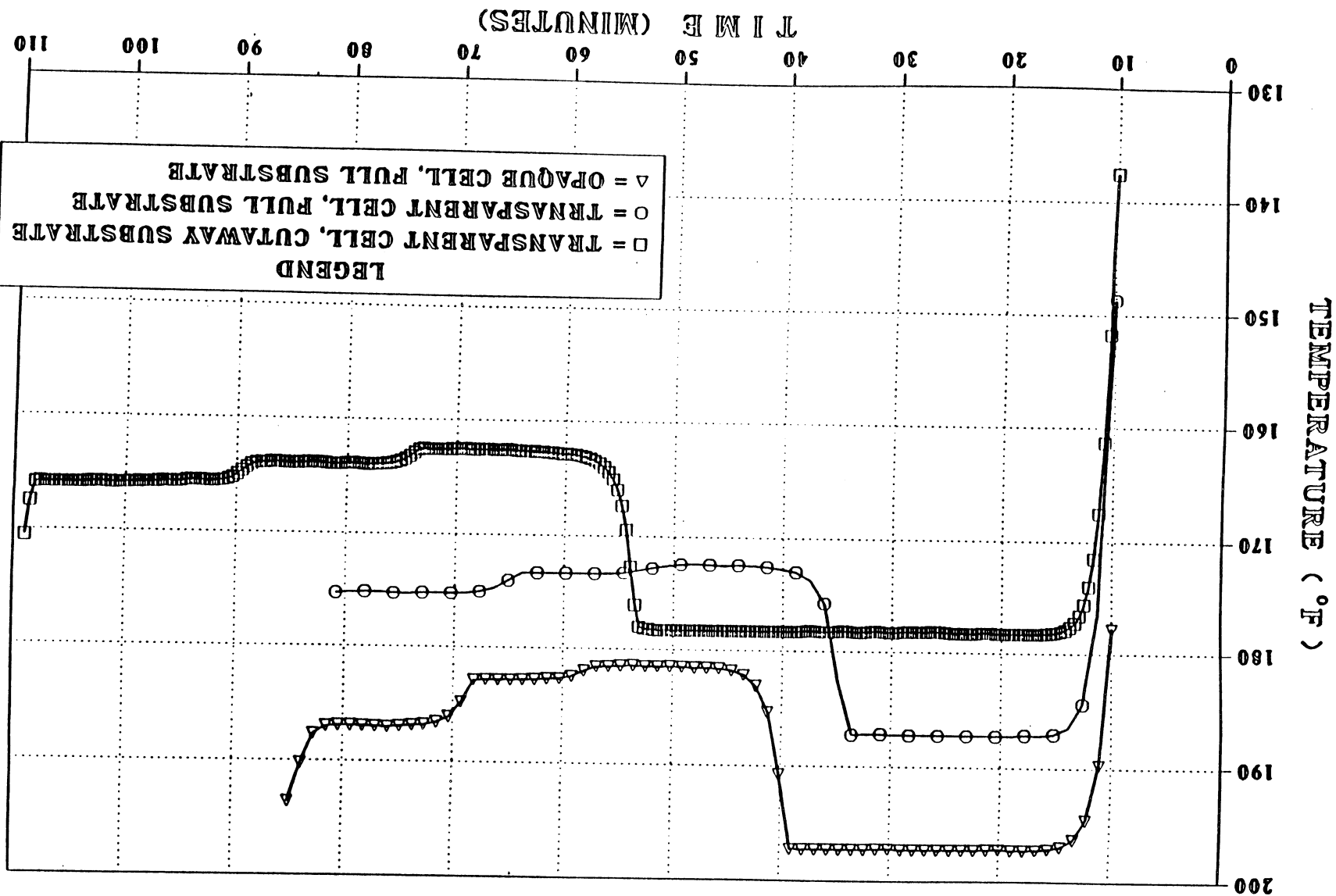


PREDICTED SOLAR CELL TEST TEMPERATURES

FOR THREE ARRAY DESIGNS

SOLAR = 1.0, ALBEDO = 0.30

POWER CIRCUIT #2



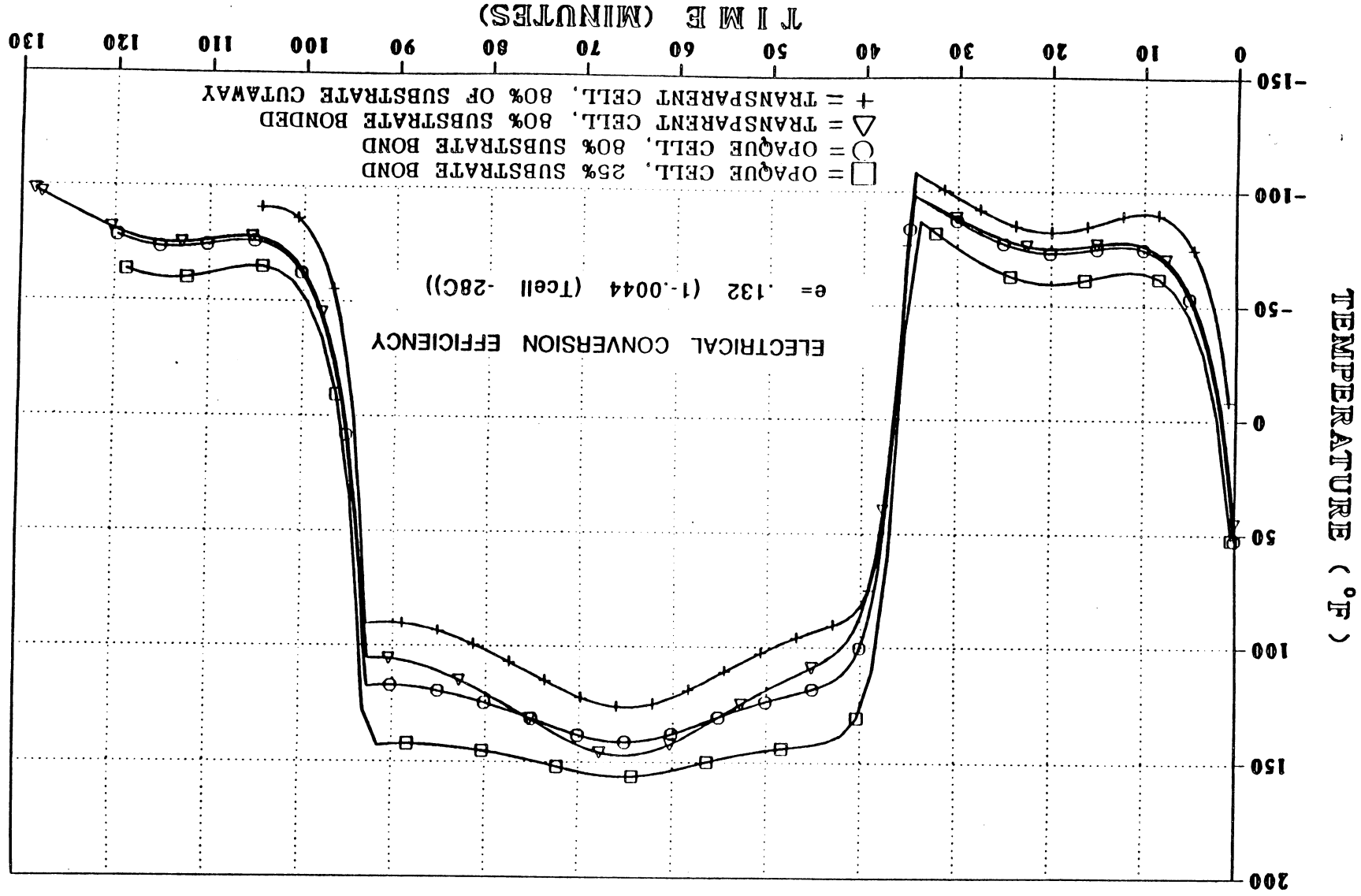
DESIGN CHANGES TO IMPROVE CELL THERMAL PERFORMANCE

- BOND SUBSTRATE TO CELL BACKFACE WHERE POSSIBLE
- REDUCES RADIATION SHIELD EFFECT
- ACRYLIC TRANSFER TAPE OR SILICONE ADHESIVE
- WITH CUTAWAY SUBSTRATE ADD COATING TO INCREASE EMISSIVITY OF CELL BACKFACE
- INCREASE EMISSIVITY FROM 0.6 TO 0.85
- TRANSPARENT TO SOLAR WAVELENGTHS

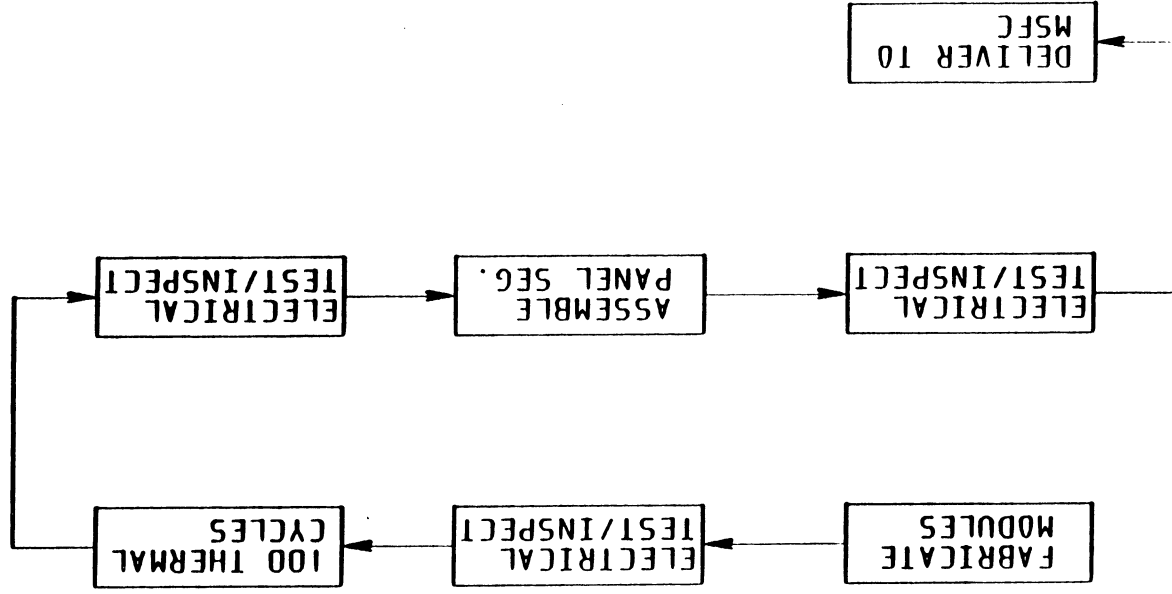
PREDICTED CELL TEMPERATURES ON ORBIT

250 NM ORBIT, BETA ANGLE = 0 DEGREES

SOLAR LOAD NORMAL TO ARRAY

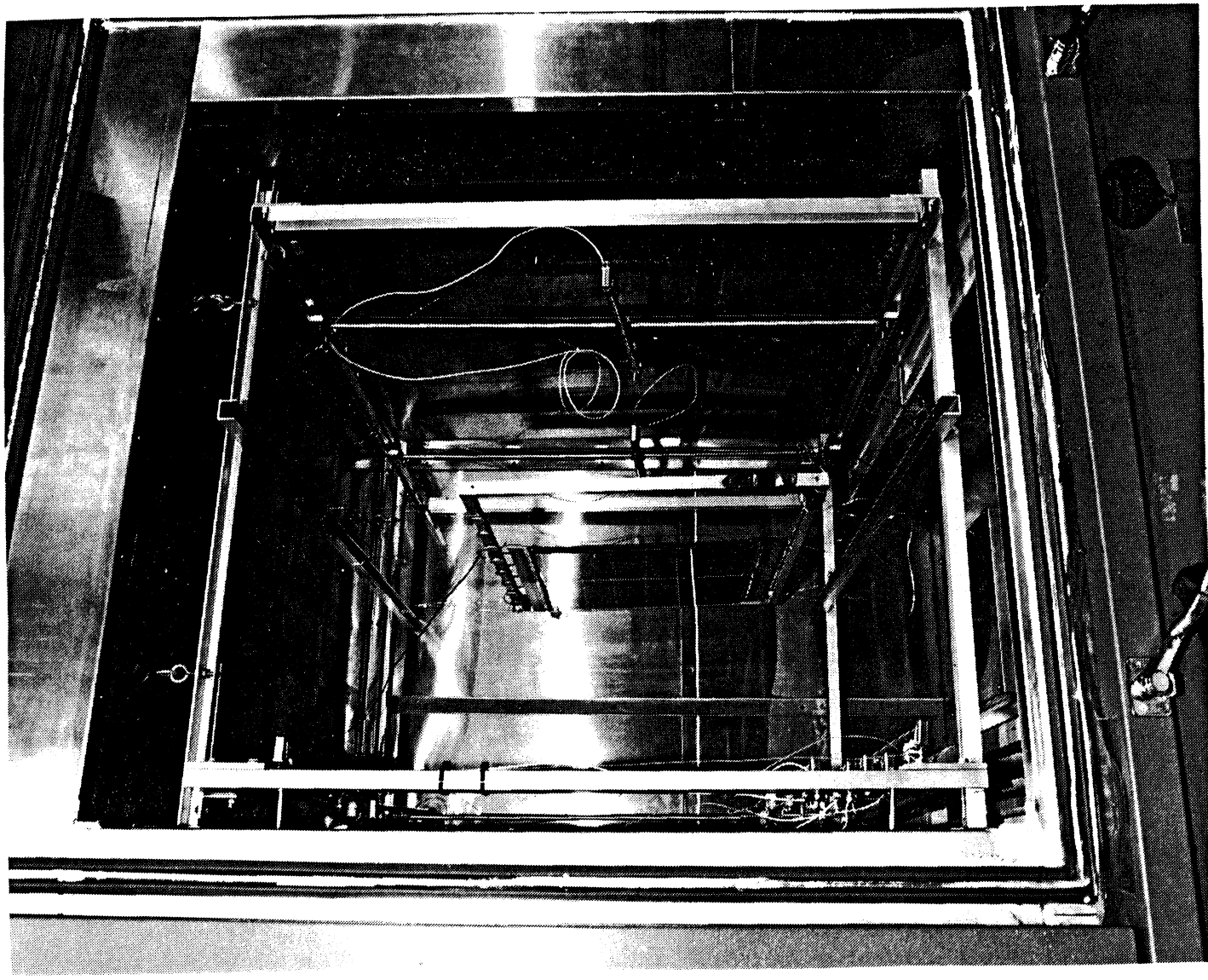


PANEL SEGMENT ACCEPTANCE TEST

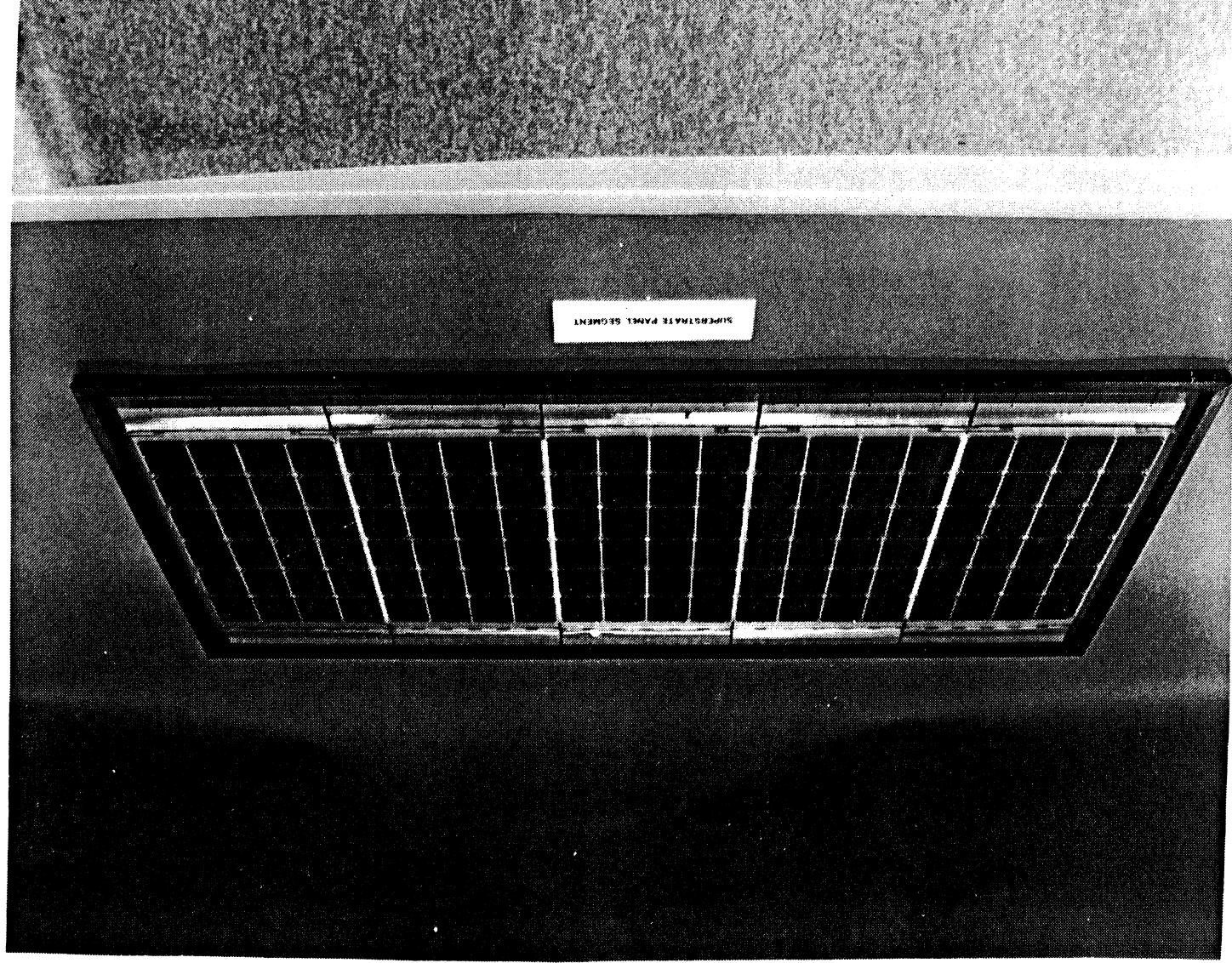


PANEL SEGMENT ACCEPTANCE TEST - FRONT SIDE

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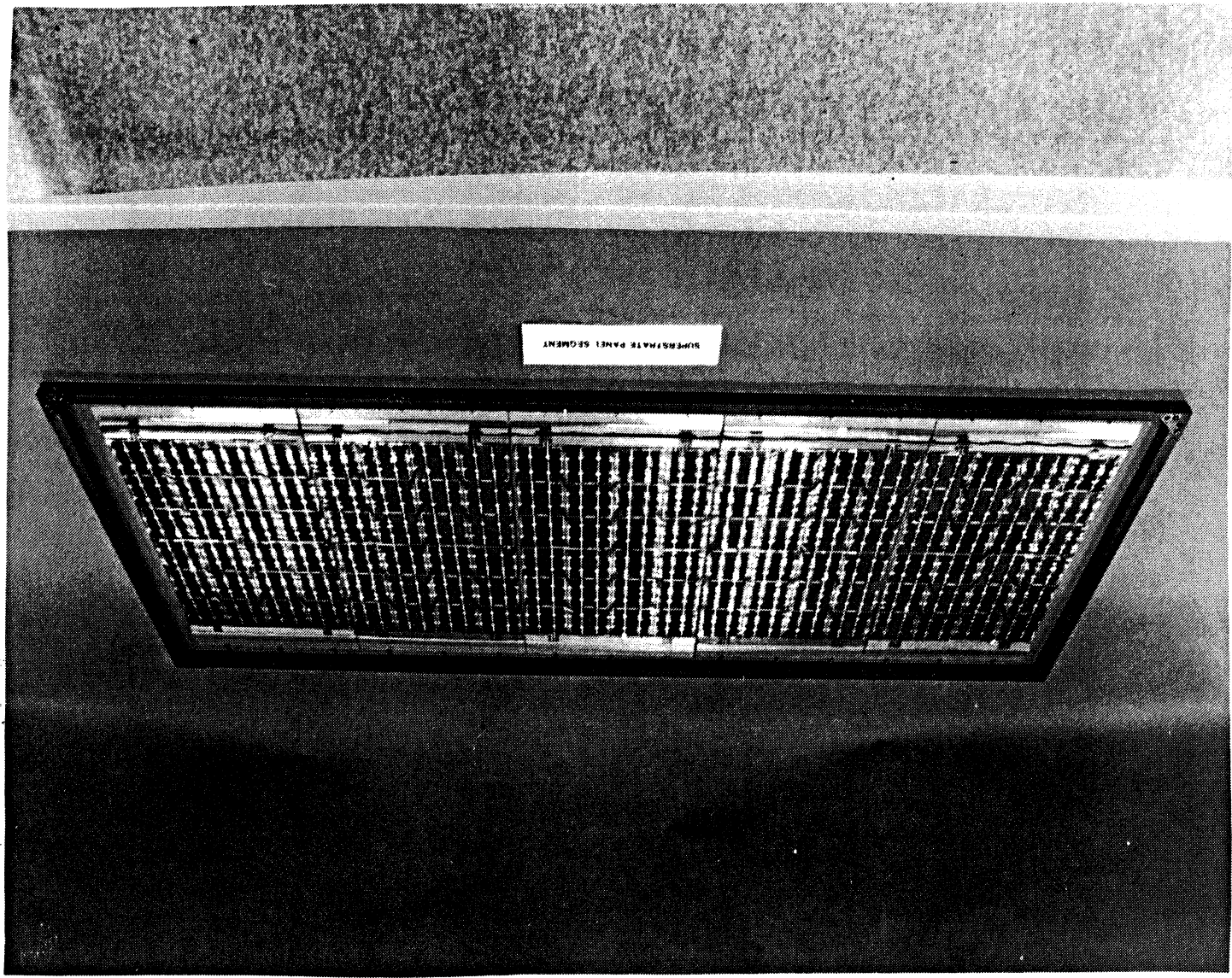


SUPERSTRATE PANEL SEGMENT - FRONT SIDE



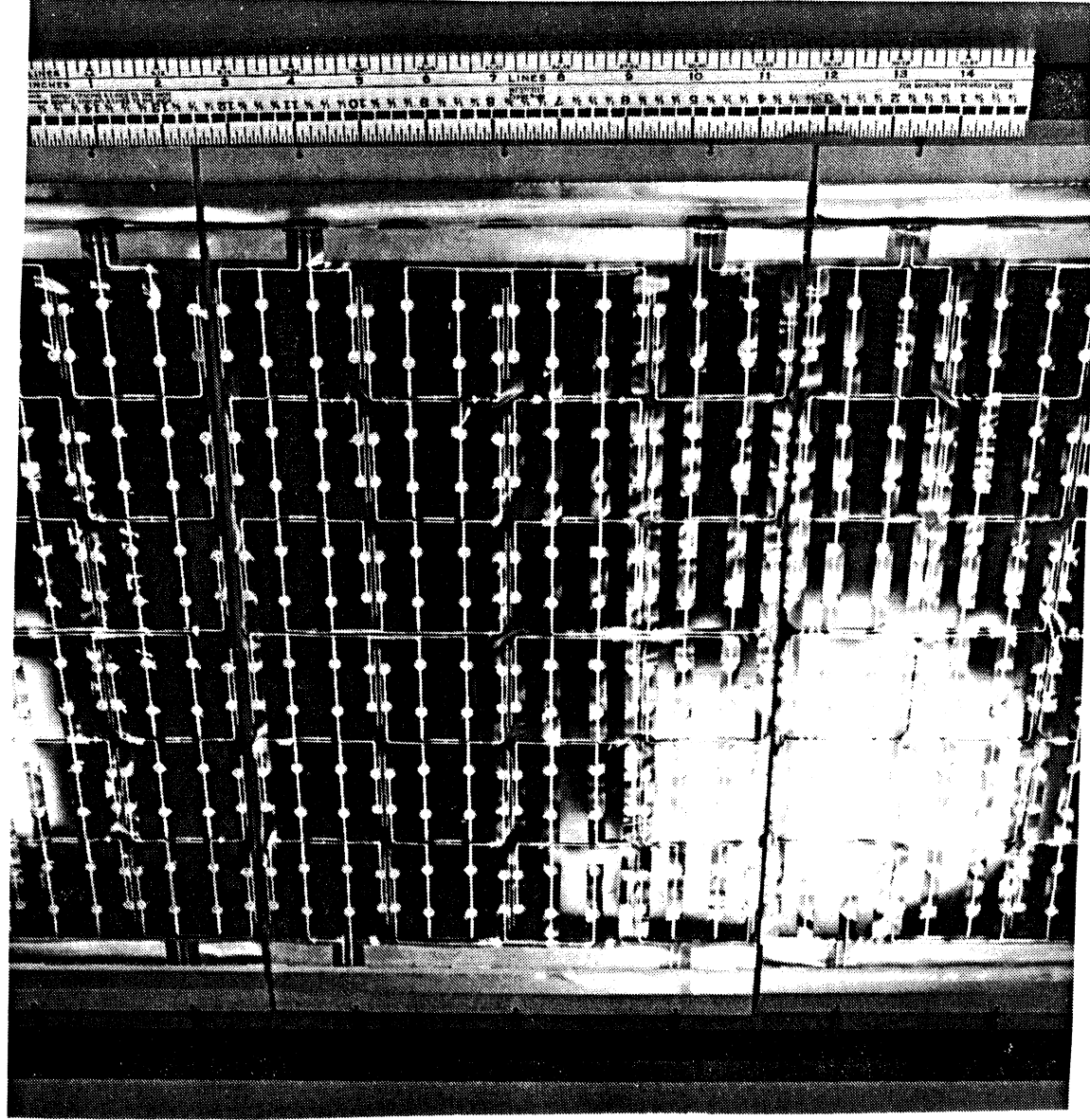
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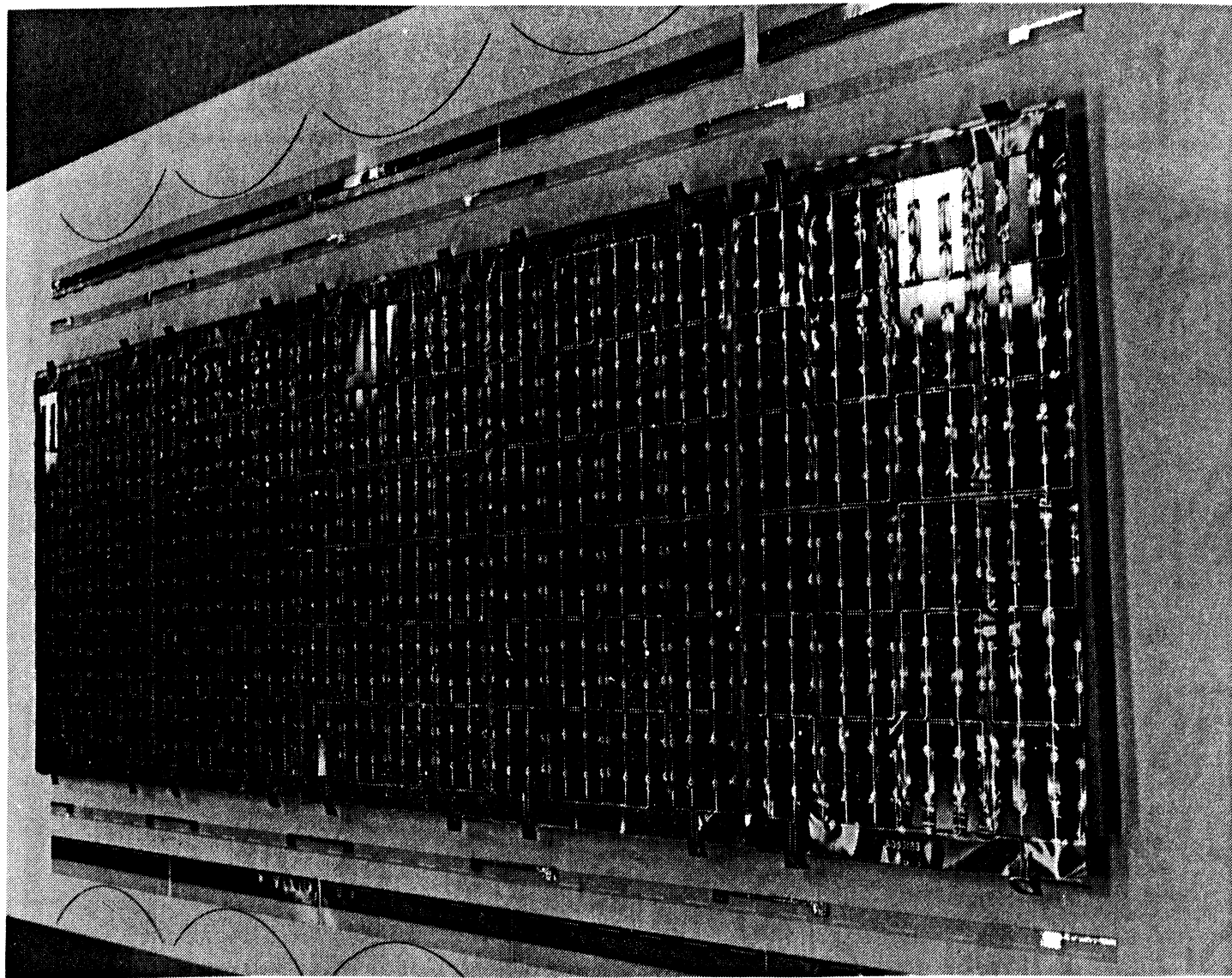
SUPERSTRATE PANEL SEGMENT - BACK SIDE

CLOSEUP OF COMPLETED SUPERSTRATE PANEL SEGMENT



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OF POOR QUALITY

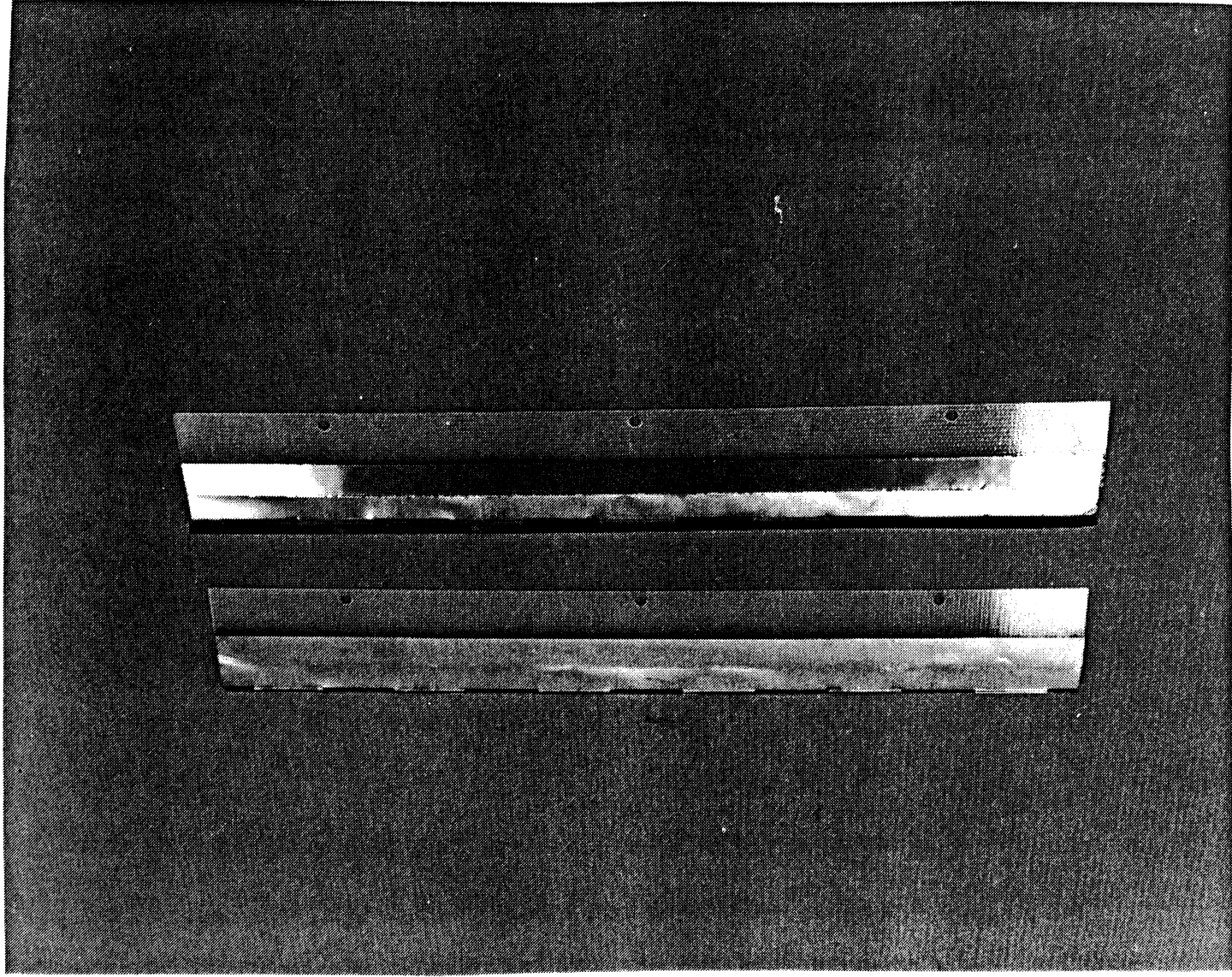
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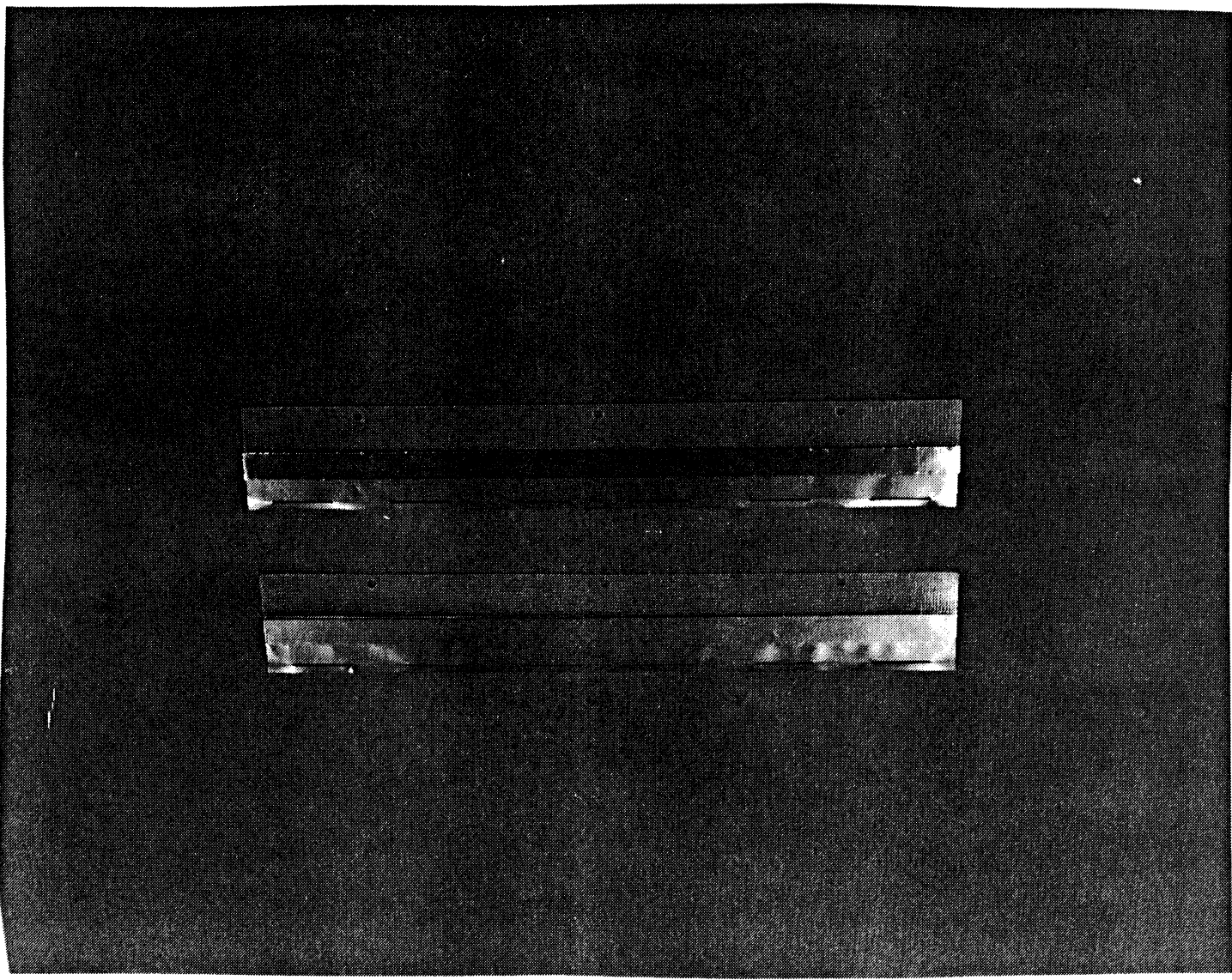
DISASSEMBLED SUPERSTRATE PANEL SEGMENT

FORMED FIBERGLASS/MOLY HINGES FOR PANEL SEGMENT

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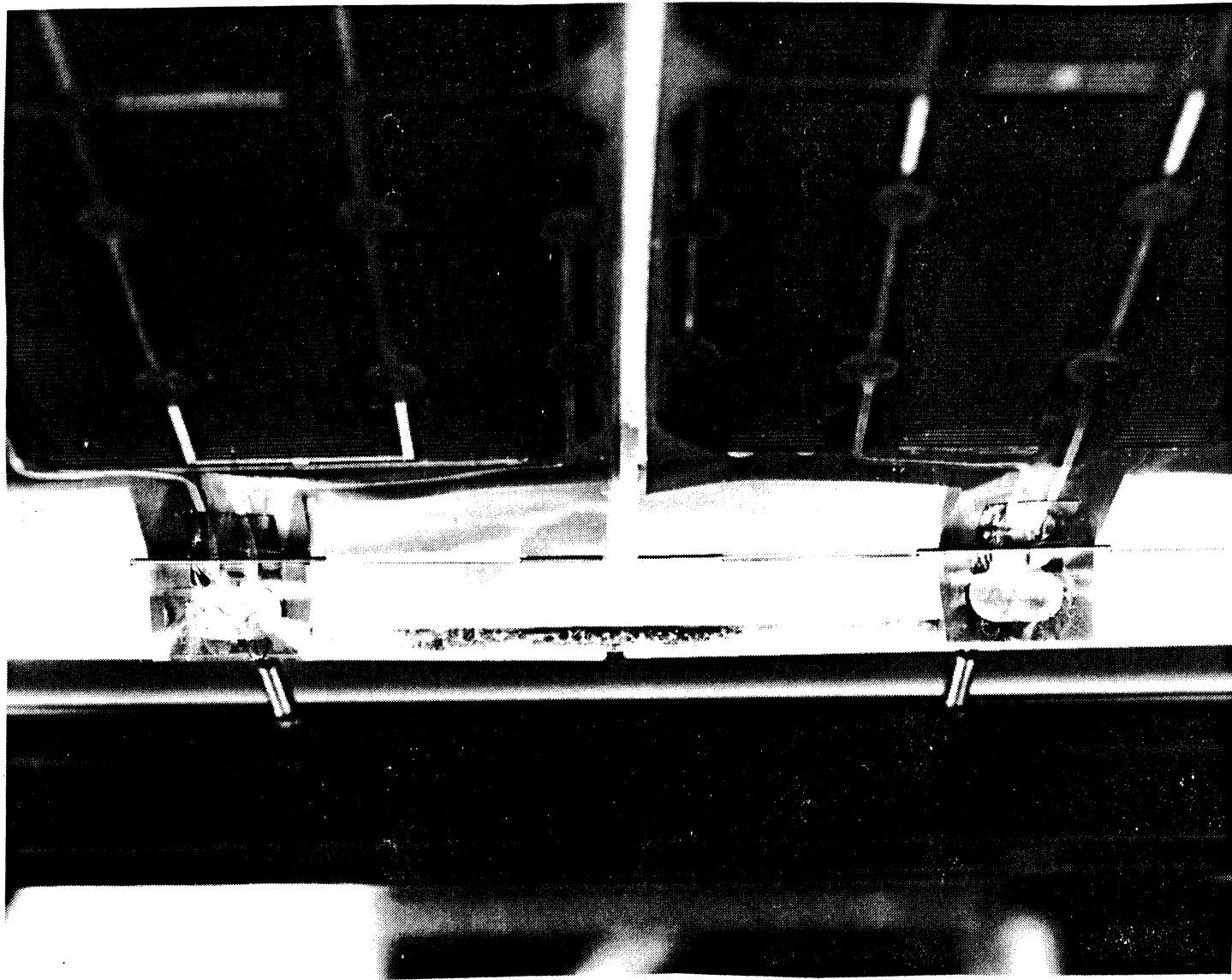


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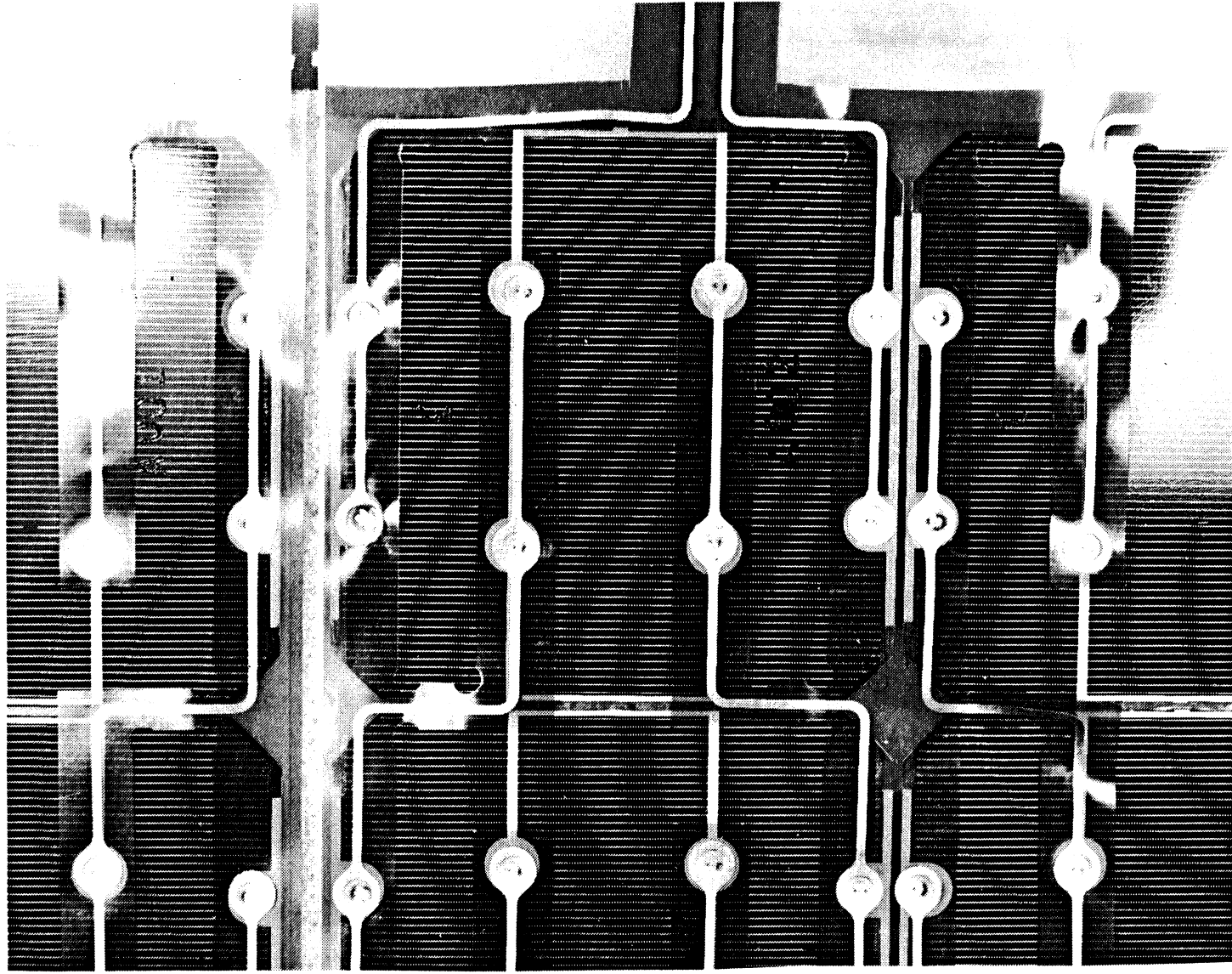
FIBERGLASS/MOLY HINGES FOR PANEL SEGMENT

**ELECTRICALLY CONNECTING TWO SUPERSTRATE
MODULES WITH JUMPER - BACK SIDE**



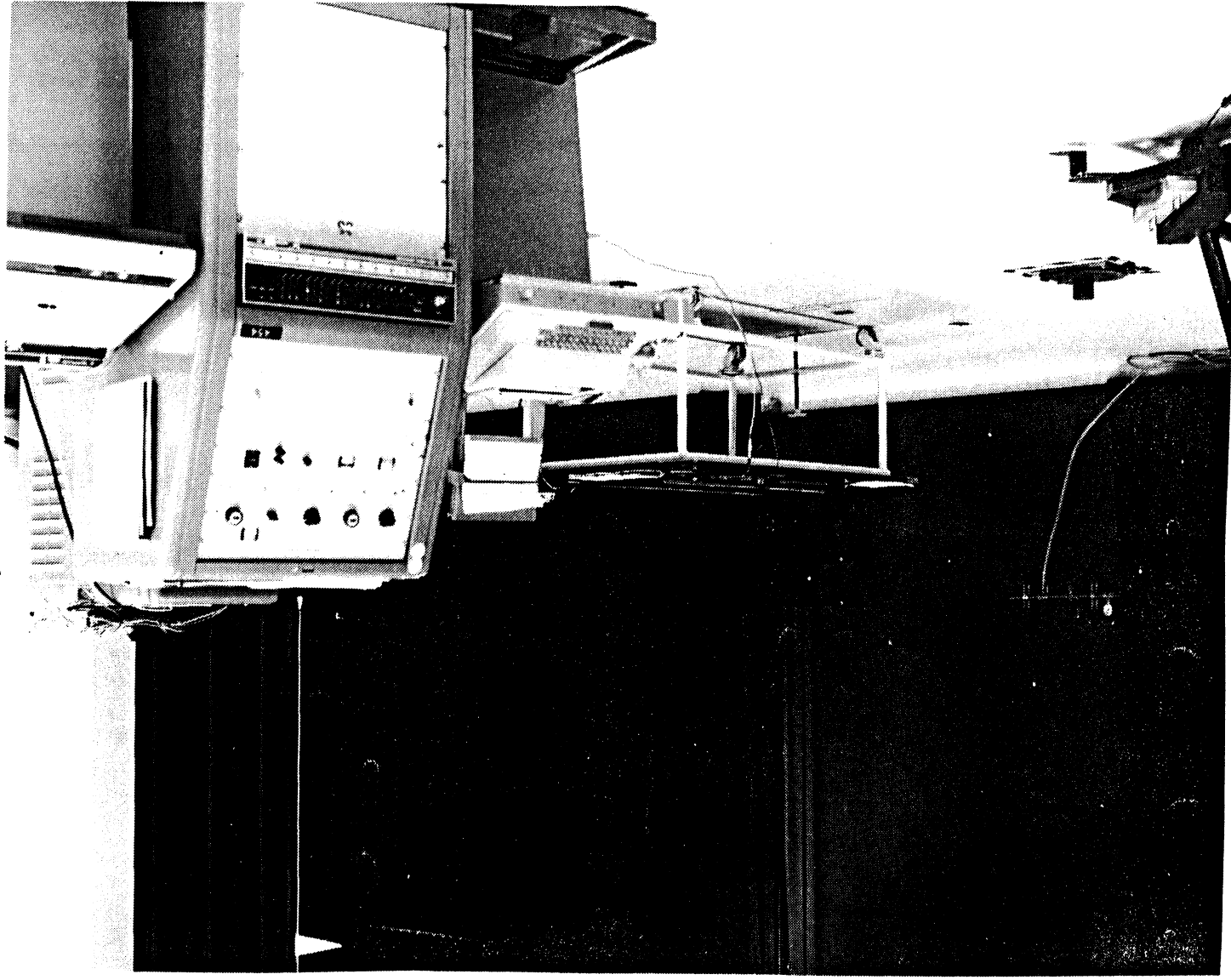
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**CLOSEUP OF CUT-AWAY KAPTON INTERCONNECT
WELDED TO SUPERSTRATE ASSEMBLY**



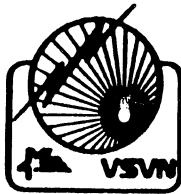
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SETUP FOR ELECTRICAL TESTING OF PANEL SEGMENT



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SUMMARY



- DEVELOPED PROCESS FOR MANUFACTURING SUPERSTRATE ASSEMBLIES
- FABRICATED TEN SUPERSTRATE MODULES AND TWO CONVENTIONAL MODULES
- THERMAL CYCLED THREE MODULES 2000 CYCLES IN LMSC'S "QUICK LOOK" THERMAL CYCLE CHAMBER
- PERFORMED THERMAL BALANCE TEST AT BOEING
- DELIVERED PANEL SEGMENT TO MSFC
- DETAIL DESIGN AND ANALYSIS OF SOLAR ARRAY MING CANCELLED UNTIL FUTURE FUNDS ARE AVAILABLE
- FABRICATION OF MING SEGMENT CANCELLED UNTIL FUTURE FUNDS ARE AVAILABLE

ADDITIONAL WORK



- COMPLETE REMAINDER OF TASKS FOR ADVANCED PLANAR ARRAY DEVELOPMENT FOR SPACE STATION (APAD55)
- INVESTIGATE EDGE PREPARATION TECHNIQUES FOR SUPERSTRATE GLASS
- INVESTIGATE USING SILICONE SHEET ADHESIVE (DC X4-46435) FOR SUPERSTRATE BONDING
- EVALUATE GLASS ENCAPSULATED SUPERSTRATE MODULES
 - PROTECTS AGAINST ATOMIC OXYGEN EROSION
 - LONGER THERMAL CYCLING CAPABILITY